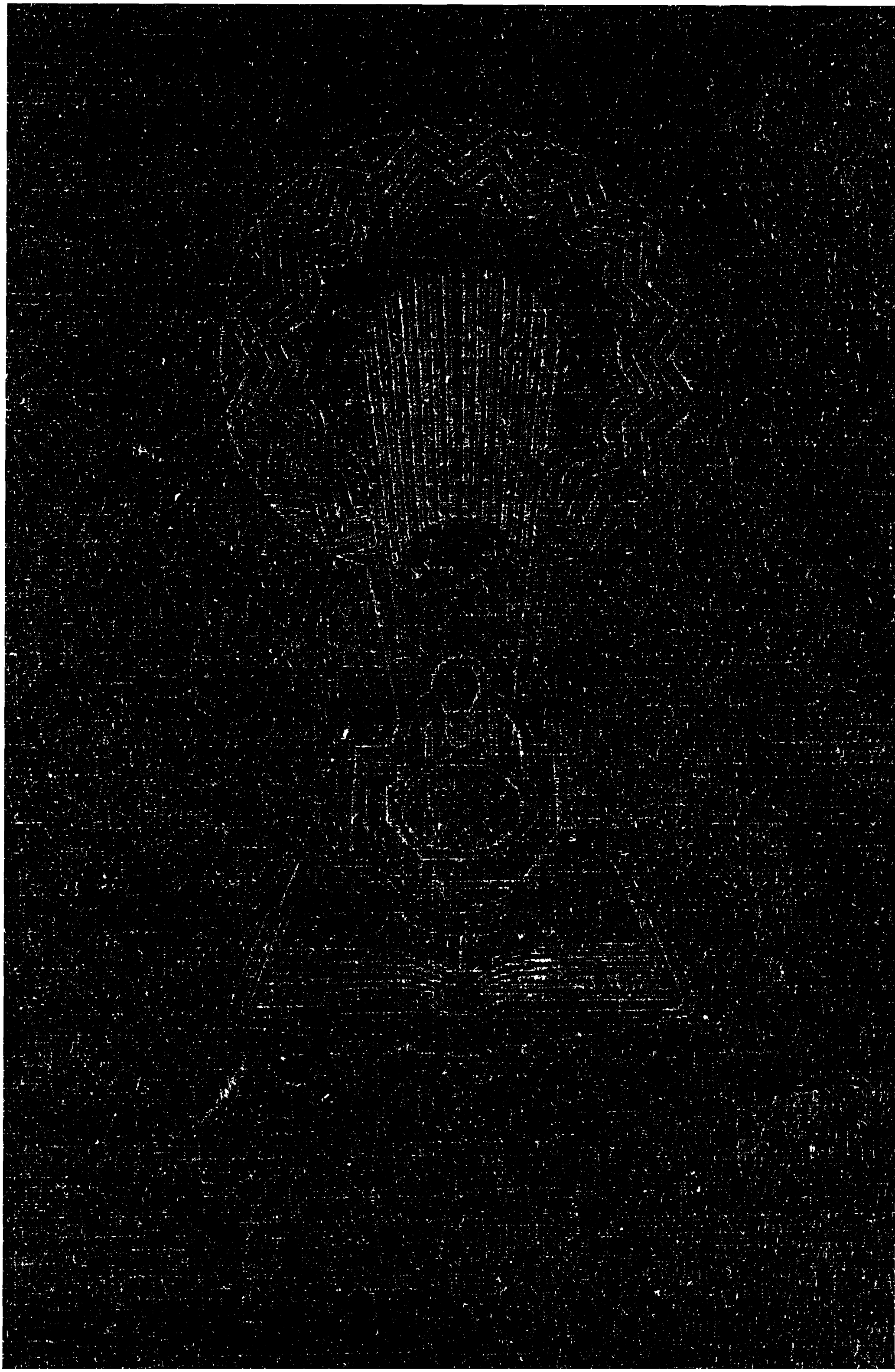
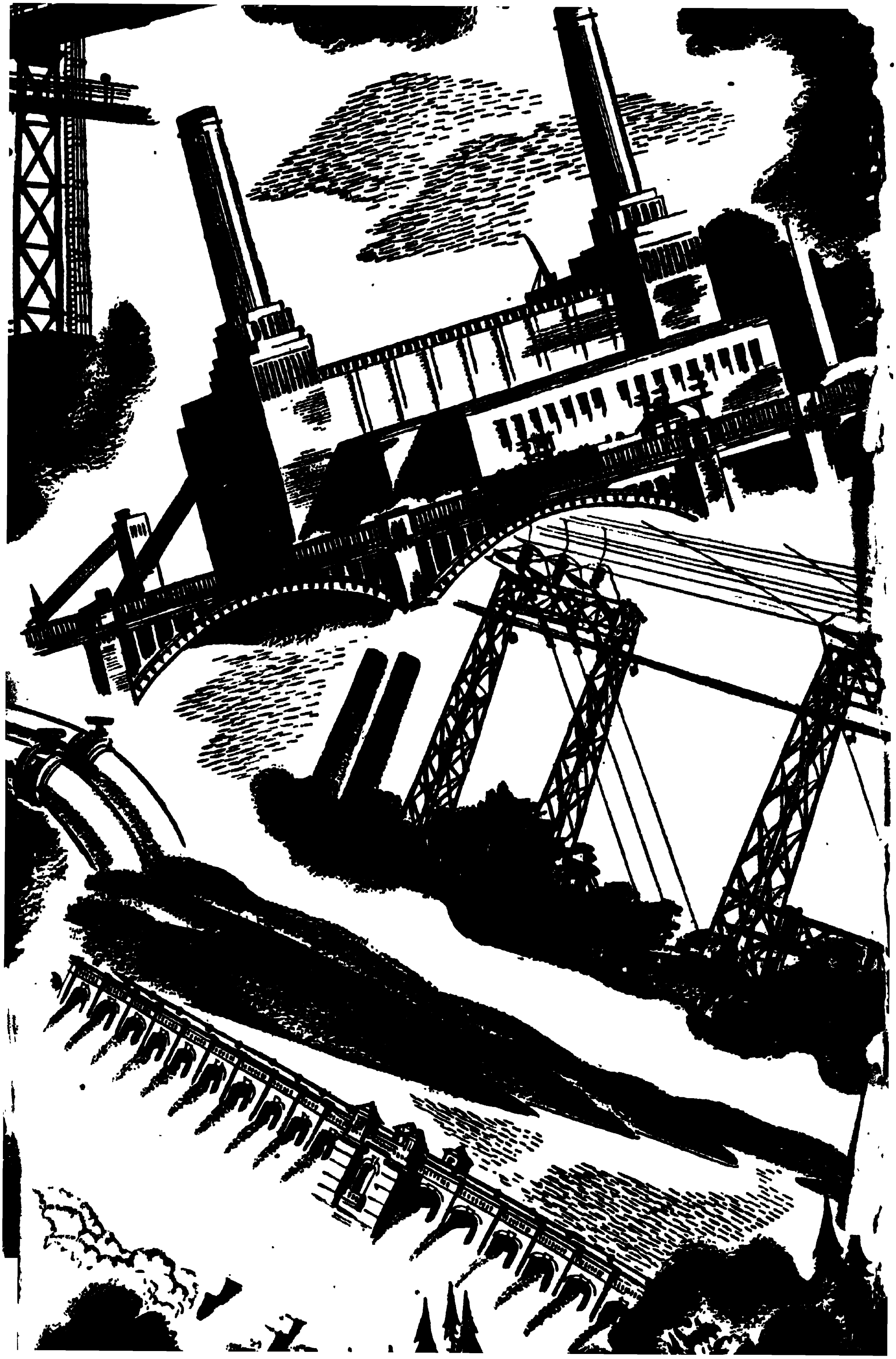
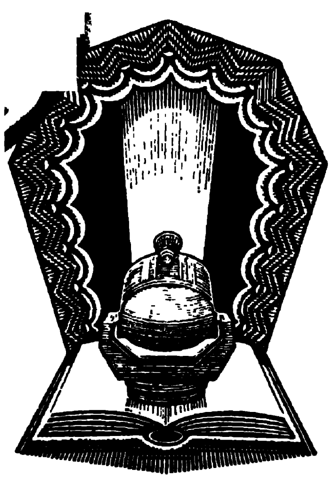


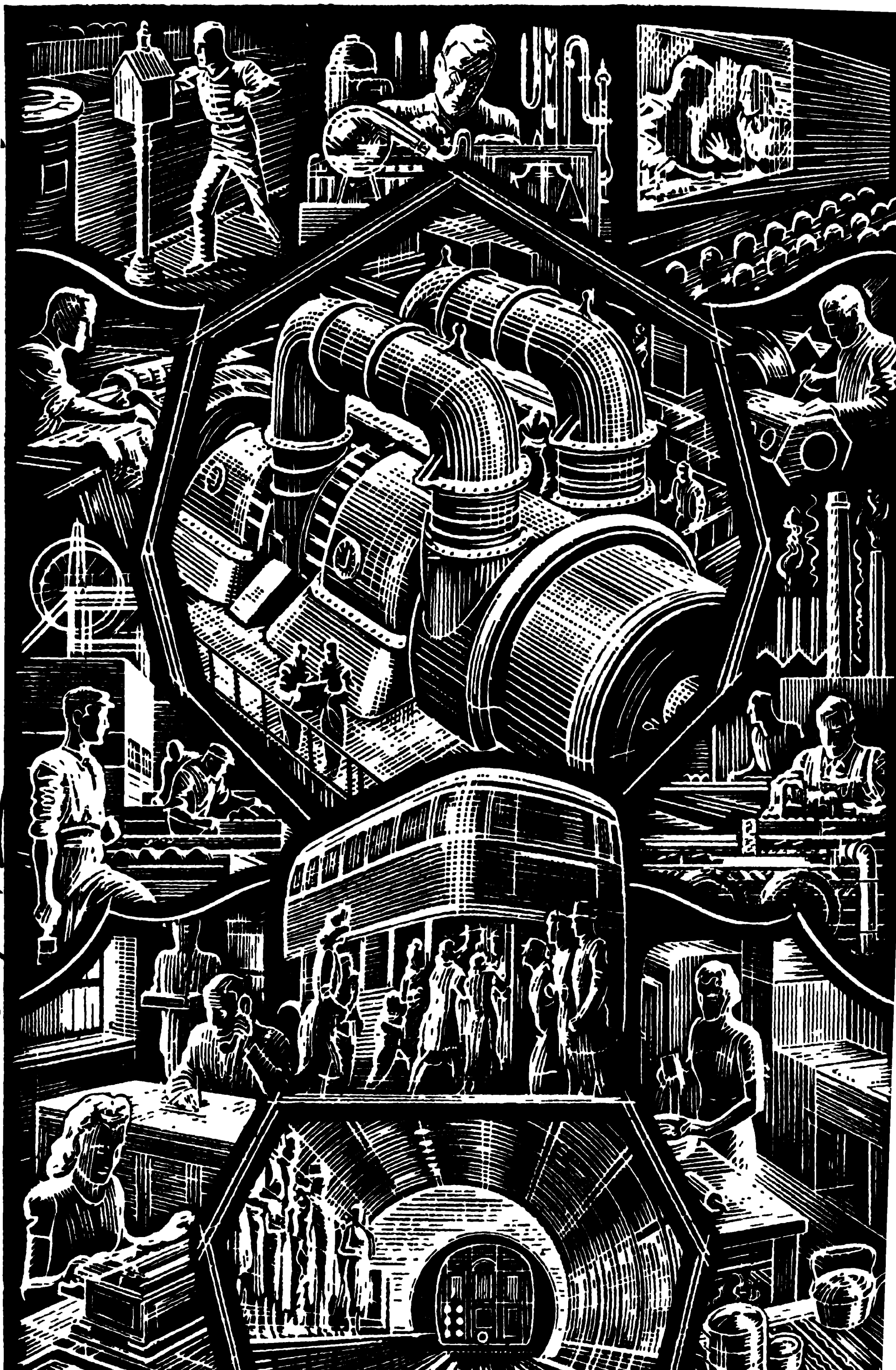


EVERYDAY KNOWLEDGE IN PICTURES

Showing how Coal, Gas, Electricity and Water are produced and distributed. How Telephones, Clocks, Radio Sets, Domestic Appliances and Safety Devices work. How Transport Systems are operated. How Cinema Films are projected and Gramophone Records made



ODHAMS PRESS LIMITED, LONG ACRE, LONDON, W.C.2
1921



CONTENTS

	PAGE
HOW COAL IS BROUGHT TO YOUR HOME	4
HOW DOMESTIC GAS IS PRODUCED AND SUPPLIED	30
HOW WE HARNESS ELECTRICITY	52
HOW WATER COMES TO YOUR TAP	70
HOW YOU GET YOUR HOUSEHOLD HOT WATER	87
WHAT HAPPENS WHEN YOU TELEPHONE	99
HOW YOUR CLOCK TELLS THE TIME	115
HOW YOUR REFRIGERATOR WORKS	131
HOW A LAUNDRY WASHES YOUR CLOTHES	139
HOW A VACUUM CLEANER SWEEPS YOUR ROOMS	151
HOW A TUBE RAILWAY WORKS	158
WHAT HAPPENS WHEN YOU POST A LETTER	180
WHAT HAPPENS WHEN YOU SEND A TELEGRAM	196
HOW BUS TRANSPORT IS ORGANIZED	206
HOW TRAFFIC LIGHTS WORK	223
WHAT HAPPENS WHEN YOU SOUND A FIRE ALARM	227
HOW THE WEATHER IS FORETOLD	233
HOW CANAL LOCKS WORK	242
HOW CINEMA FILMS ARE PROJECTED	252
HOW FIRE EXTINGUISHERS AND SPRINKLERS WORK	261
WHAT HAPPENS WHEN YOU USE A LIFT	266
HOW AN AIR-CONDITIONING PLANT WORKS	277
HOW YOUR RADIO SET WORKS	285
HOW YOUR GRAMOPHONE RECORDS ARE MADE	299
INDEX	318

AT THE PIT-HEAD

Inevitable landmark of mining districts is the headgear frame. The picture shows the typical steel lattice at the Rhondda Duffryn Colliery in the Rhondda Valley, Wales. Between shifts men are returning to the mine, and waiting at the lamp house. A line of trucks runs alongside.

HOW COAL IS BROUGHT TO YOUR HOME

What coal is. Sinking a mine shaft. Ventilating and draining the mine. Dangers—gas and explosion. The safety lamp. Methods of working. The miner's tools. Bringing coal to the surface. The conveyor. The winding engine. The headgear frame. Sorting the coal. The depths of mines.

FOR millions of years the coal which we burn has been imbedded in the earth's crust. Before examining the methods whereby it is made available for our use, let us see what coal is, and how it came to be where we find it. The story is an impressive one.

Most people are aware of the fact that coal was originally a vegetable growth; not just the timber of vast forests, but also the enormous accumulations of smaller growths such as ferns and mosses. There is ample evidence that the growth was on a scale quite unparalleled by anything to be found today. Three hundred million years ago, that is to say the number of years ago since the First Dynasty of Babylon multiplied by about 75,000, the crust of the earth was still unstable, volcanic action was at work everywhere, and the outlines of land and sea bore no resemblance whatever to those now existent. Plant life flourished out of all proportion, because the climate was moist and humid, and also on account of the volumes of carbon dioxide gas emitted by numerous volcanoes in almost continuous eruption.

Indeed, it must have been easy for some other forms of life too, for fossil remains, found in the coal measures, give evidence of insects on a large scale, dragon-flies with a wing span of nearly 30 in., and cockroaches—of which there were some 800 varieties—4 in. long.

The level of the continents was low, and their surfaces were periodically flooded by the shallow seas. In this way great swamps were formed in which the vegetation flourished, only to fall and decay, gradually building up layers as the seas receded, permitting growth to go on again (Fig. 1).

COAL IN THE MAKING

Due to the constant flooding of these enormous forest tracts, both by sea and river action, deposits of alluvial soil were laid over them. Later on a period of very unstable conditions developed, when considerable upheavals of the land surfaces took place, with consequent submerging of other parts below the sea (Fig. 2). In the course of the millions of years that followed, periods unfavourable to the growth of these forests occurred, and no further additions to the great beds of decayed matter were made. Great rivers flowed down to the oceans over them, depositing ever-increasing thicknesses of alluvial soil, on a scale unimaginable. The weight of these layers squeezed the accumulations below with inexorable pressure, that increased with the additions above as time went on, the resulting series of layers forming into rock under the load.

The original seams were more or less level, but they had been violently displaced by earthquake action. Subsequent

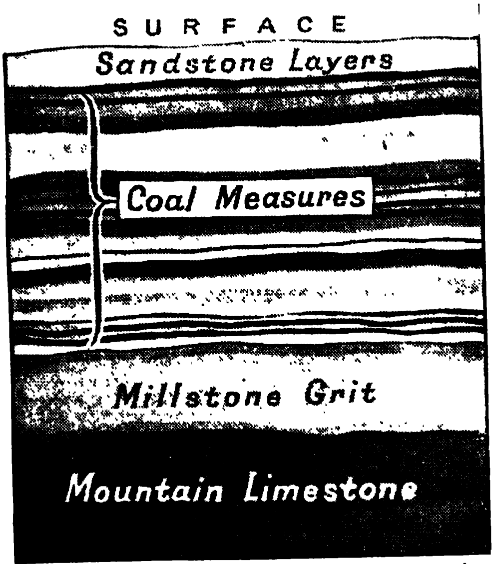


Fig. 1. Layers were built up from the vegetation which decayed in great swamps.

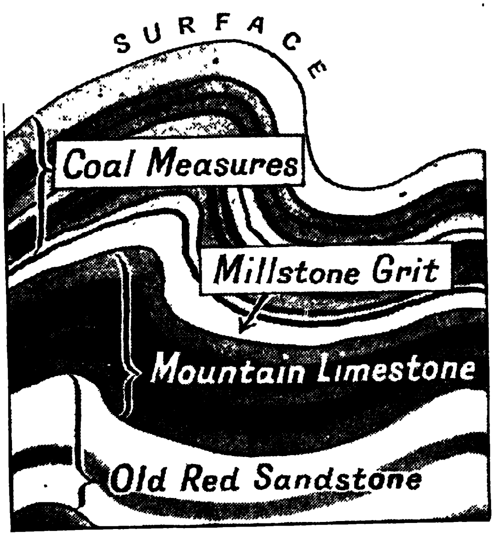


Fig. 2. The strata became folded because in a period of unstable conditions parts of the earth's crust heaved up and others sank down.

HOW COAL MEASURES TOOK SHAPE

In Fig. 1 each black line represents a coal forest that grew, died, and was compressed into peat and finally into coal. Vast upheavals of the earth's crust folded the strata (Fig. 2). Countless ages of weathering wore down the uneven surface. Rivers and seas deposited fresh layers on top, and the coal measures were buried again (Fig. 3). Weathering in some cases laid the seams bare, causing an outcrop running to the surface (Fig. 4). When the strata slipped, a fault was caused, the seam stopping short (Fig. 5.)

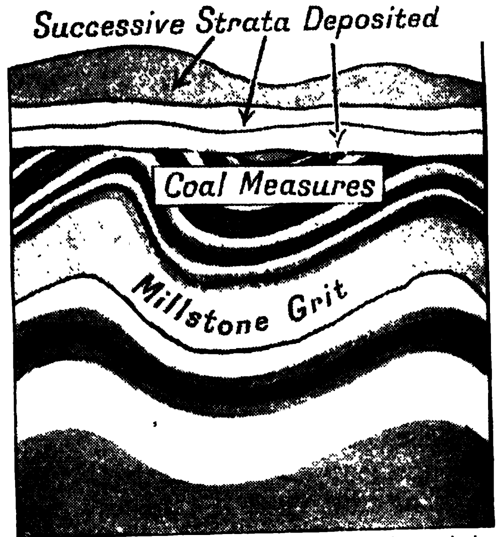


Fig. 3. The coal measures were buried by layers of sand, soil or chalk compressed into rock.

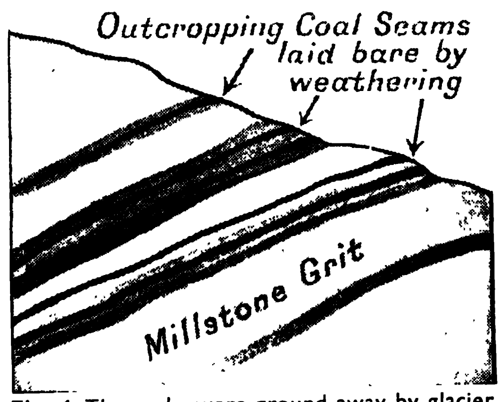


Fig. 4. The rocks were ground away by glacier action, exposing the coal in outcropping seams.

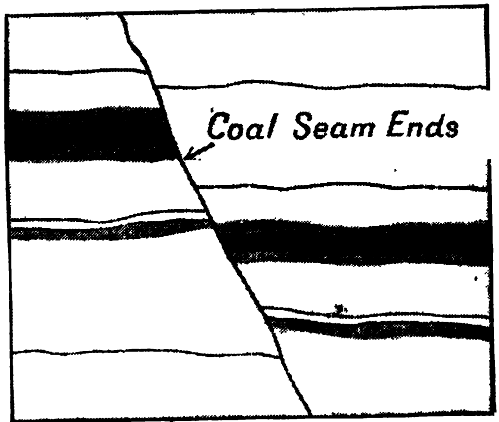


Fig. 5. Geological faults were caused by weakness in the underlying strata, breaking the seam.

weathering levelled the surface, exposing the seams in places. Over this surface additional layers of soil were deposited, sand, or chalk, which was compressed into rock by the enormous accumulation of weight above, until we find a section something like that shown in Fig. 3. The coal measures consist of numerous seams of coal alternating with bands of stone, laid on the lower stratum of millstone grit, immensely older, and that, in turn, over old red sandstone, one of the oldest of the world's rocks.

Occasionally formations as shown in Fig. 4 are found, where the deposited rocks have been ground away by glacier action, exposing the ends of the coal seams. No doubt the original discovery of the black stone—coal—was due to such formations as this.

Due to weaknesses in the underlying strata, a geological accident, known as a fault (Fig. 5) often occurs, resulting in the apparent disappearance of the seam. Observation of the lie of the strata then tells the miner whether he must seek higher or lower for its continuation.

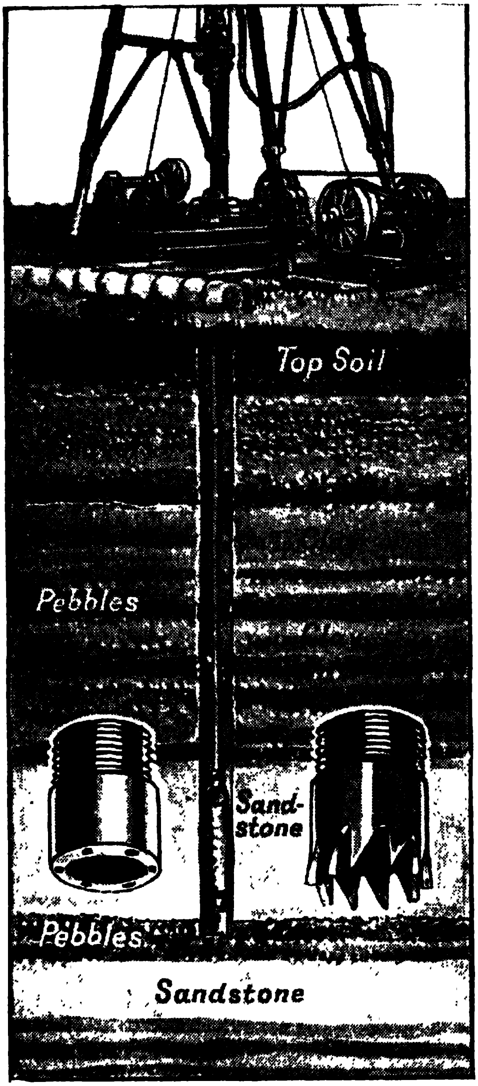
THE QUALITY OF COAL

The coal found in the lower seams is, as a rule, of better quality, owing to the greater pressure to which it has been subjected. Anthracite is a case in point. Brown coal, or lignite, is immature coal that is really only in course of formation, and is of poor quality as a fuel.

The fuel value of coal is due to the fact that it is composed of complex carbon compounds containing oxygen and hydrogen, and carbon and hydrogen are

HEWING COAL A THOUSAND YARDS BENEATH THE SURFACE

Sequel to the eventful history shown in diagram on the opposite page—the coal, which it has taken millions of years to convert into fuel, is hacked out by a helmeted miner.



PROSPECTING FOR COAL

Fig. 6. Making a trial boring. Sections of the strata are cut out and brought to the surface for inspection. Inset are: (*left*) a diamond tool, and (*right*) a calyx tool used in the process.

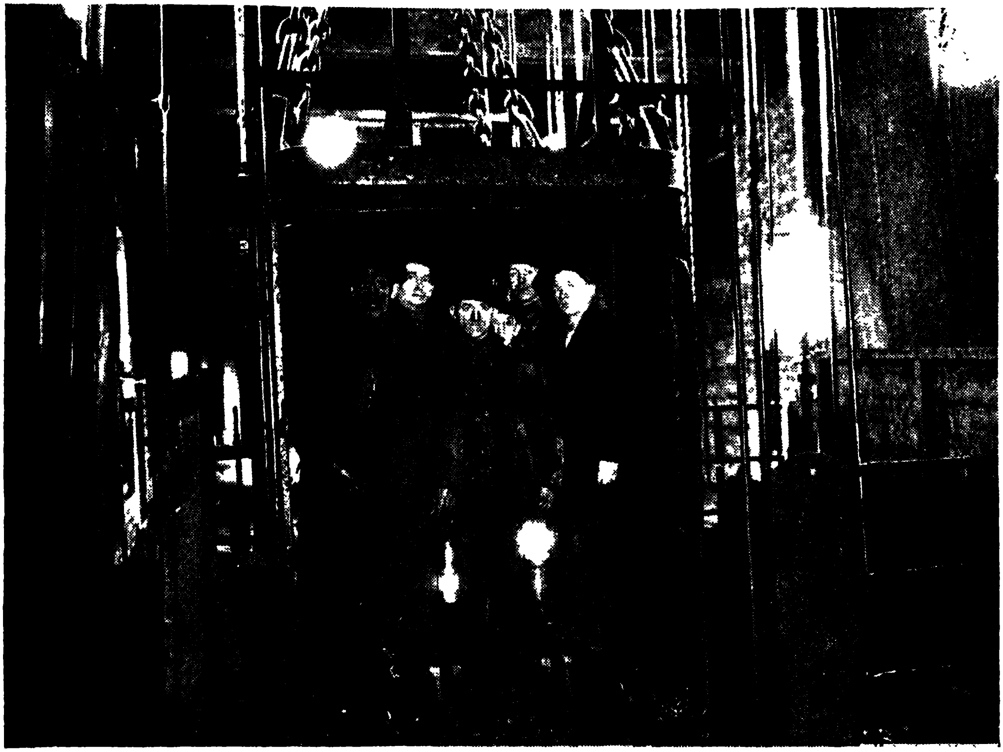
the two principal fuel elements. But there are so many grades of coal, each one with properties of its own that it must suffice to say that the proportion of carbon may be between 70 and 93 per cent, the first representing the brown coal or lignite, and the second, anthracite of best quality. Hydrogen content varies between 3 and 6 per cent, and the balance would be made up from oxygen, nitrogen, and sulphur in small quantity.

The fuel technologist thinks in terms of what he calls calorific value, which, in simple language, means just how much useful heating work the fuel will do. Could we burn the coal to the best possible advantage—which, unfortunately, we never do—we might expect that a pound by weight of a good grade of household coal would turn 10 lb. of water into steam, after bringing the former to boiling point from a temperature of 60 degrees Fahrenheit. Actually, only about 7 lb. would be so evaporated, and that could be done only in a good boiler, most certainly not in a household grate.

This piece of apparatus has been responsible for the casting away of millions of tons of valuable coal products, and still does so. Chemists tell us of more than 2,000 valuable substances that can be produced from coal; we can only state very briefly the principal direct derivatives from a normal quality of gas coal, and their approximate quantities.

One ton of coal yields first: 13,000 cub. ft. of gas; 10 gals. of tar; $14\frac{1}{2}$ cwt. of coke. The tar yields ammonia, naphtha, creosote, anthracene and pitch. The naphtha yields benzene, toluene and carbolic acid. So it goes on. From one product a host of others is drawn. By treating the coal in powdered form with hydrogen under enormous pressure in a steel retort a thick black oil is produced from which petrol and lubricating oil can be distilled, leaving a residue of heavy fuel oil and pitch. This is the hydrogenation process.

It is our main purpose here to see how the coal is won from the seam far down below the earth's surface, where it has lain for millions of years. Prospecting for the mineral is carried out now by making borings at points where seams are believed to lie at no very great depth. We have already seen that they may be

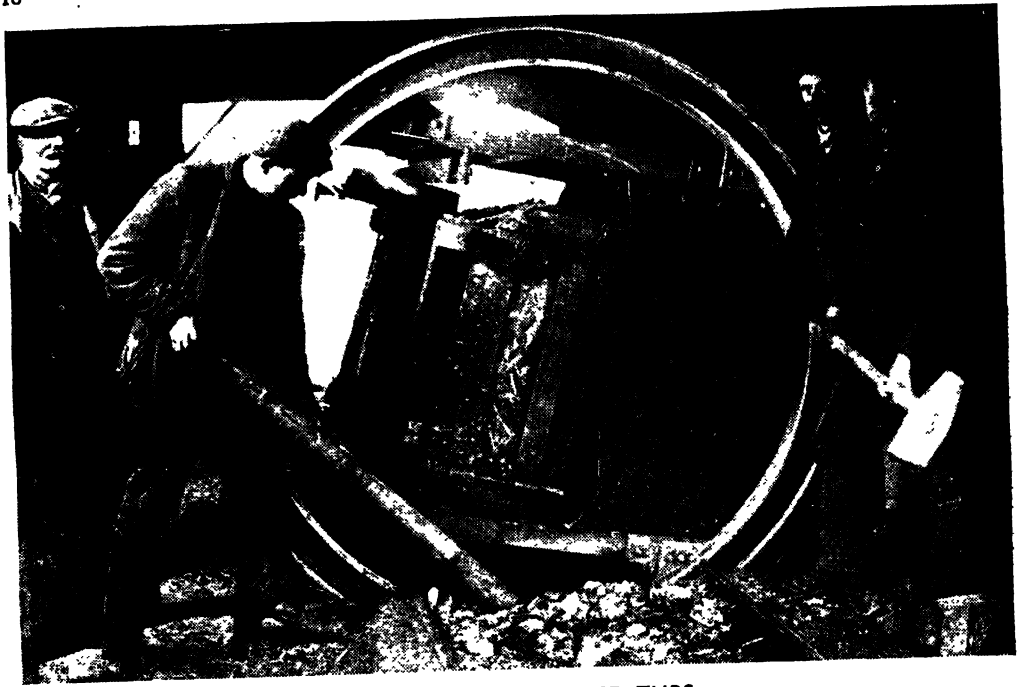


GOING DOWN THE MINE

Interior of headstock with men in cage about to descend the pit at the Amalgamated Anthracite Collieries, Cefn Coed, South Wales. Guides for the cage are enclosed in the headgear frame, the cage being hauled up and let down the shaft by means of a powerful engine and large pulleys.

UNDERGROUND TROLLEY CAR

Movement from one part of the mine to another is made easy by a rail system. Miners have special trolleys with slanting seats which enable them to keep upright on sloping ground.



EMPTYING THE LOADED TUBS

When the tubs of coal have arrived at the surface they are run out of the cage to the tipplers which turn over and deposit the coal on to the shaker screens. In the general view on pages 12 and 13 the tipplers are also seen dropping their load through to the screens and trucks.

SHAKER SCREENS FOR SORTING COAL

These screens roughly grade their contents as to size. The size of the holes is devised so that dust and small pieces are allowed to fall through. Small coal is conveniently sorted by hand.

many thousands of feet below the surface. If this is so, then there the coal must be allowed to remain for any depth below about 4,000 ft. would mean too great an expense in sinking shafts.

The prospecting tool is similar in many respects to that used in boring artesian wells. It is adapted for cutting out sections of the strata through which the shaft must pass, and bringing them to the surface. Fig. 6 shows this process and the apparatus in use, alongside is a series of cores laid out for inspection. As these sections come up, they are numbered and laid out on the ground for examination by the engineers who have to consider the practicability of sinking the shafts. The expert can tell a great deal about the probable extent of the seams from the trial borings, his judgment will decide where best to sink the shafts, of which there must be two for every new mine. The ideal arrangement must be to have them centrally placed in the field, but obviously if they can be placed close to a railway a great deal of expense will be saved in haulage.

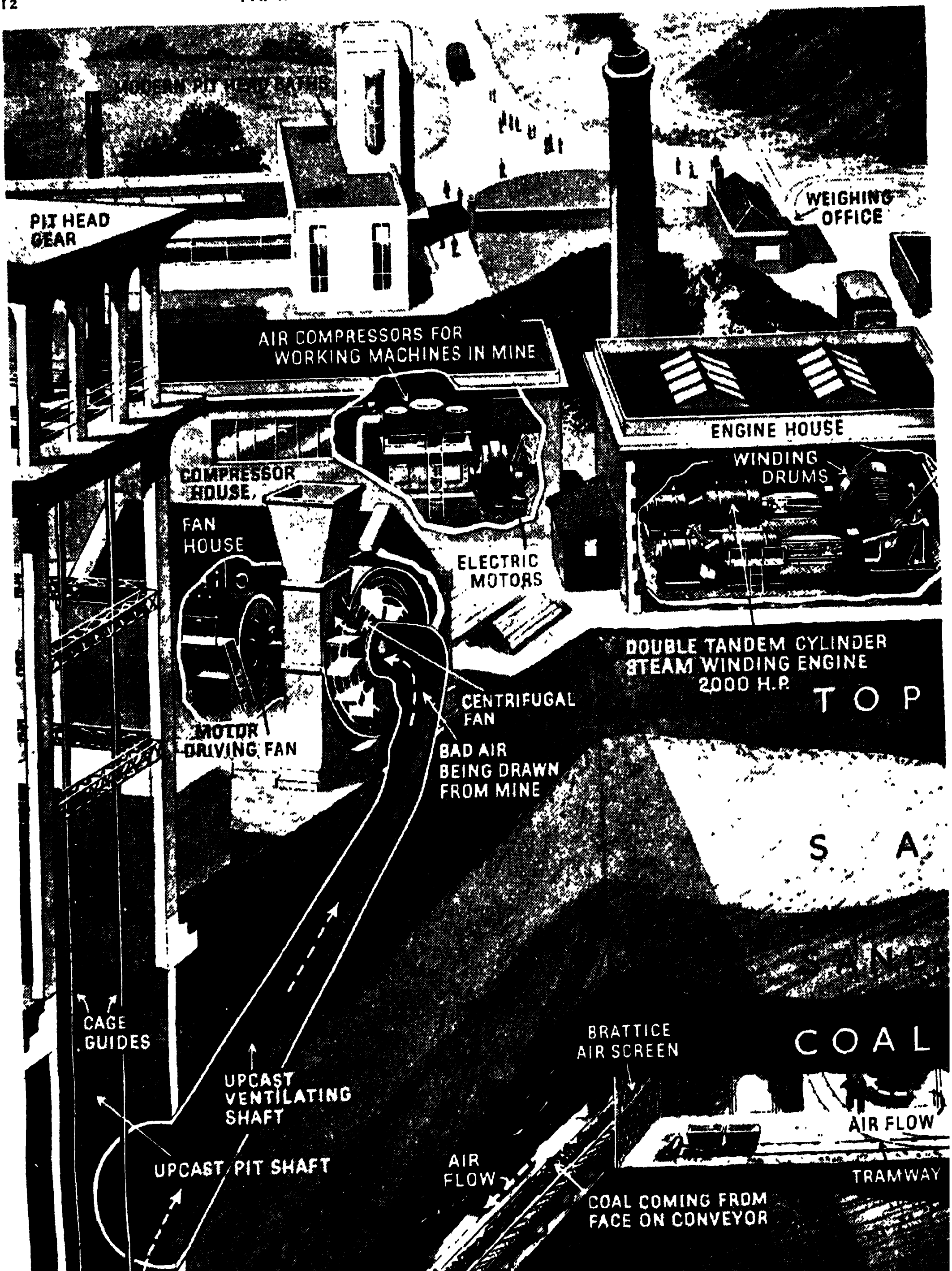
This is a matter that does not concern us; the decision to sink the shafts we will assume has been made, the main seam lying at no great depth, say about 500 ft. There is likely to be some difficulty with water, however.

Digging a hole in the ground, anything up to 20 ft. or even more across and hundreds of fathoms deep, is an expensive matter, even if all goes well. But if water flows into the hole in undue quantities the expense becomes tremendous. A certain amount of water is inevitable and can be dealt with by pumping, but if the ground is wet the sides of the hole will cave in and the brick or concrete lining will be impossible to build.

Modern methods of surmounting this difficulty are extremely ingenious, though they involve great expense. Where it is very wet indeed, the soil can be de-watered by means of a large number of perforated pipes driven well into the ground, but this system cannot penetrate to any great depth. The cementation process consists in injecting cement over a considerable area so as virtually to turn the wet material into a form of concrete, practically impervious to the water, but yet not too hard to excavate. This system is much favoured and has been brought to a fine art, so that it may be said that water no longer holds any terrors for the shaft sinkers, though it certainly adds greatly

CONTROL ROOM AND WINDING GEAR

Fig. 7. The winding gear is an important part of the mine's equipment. The ropes pass over huge pulleys at the top of the headgear frame. Many safety devices are incorporated, especially to guard against the chance of overwinding.

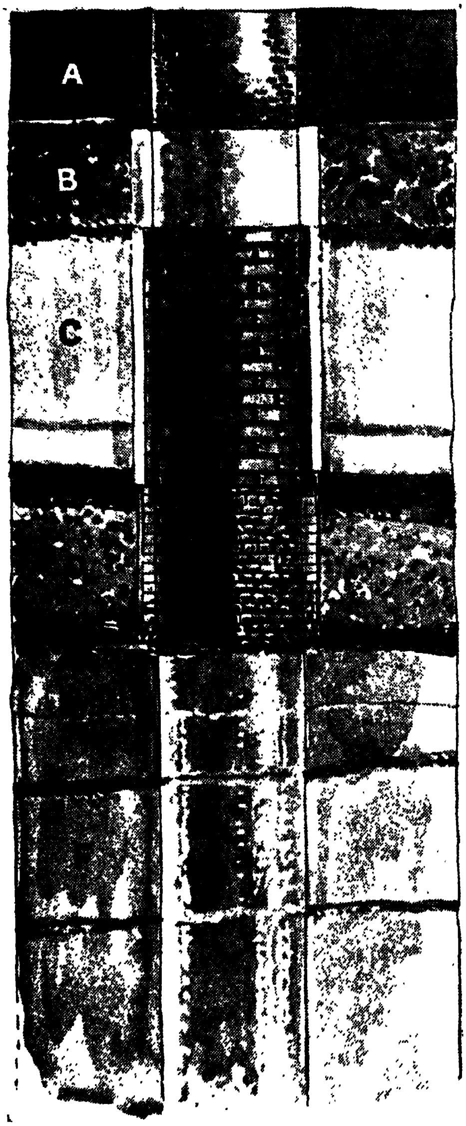


THE MODERN COAL MINE—A COMPLETE EXPOSITION

All the parts of a mine, described individually in the text and in detailed figures, are here seen as they would be in actual relation. An endless chain belt travelling on rollers brings the coal from the face to the train road. The tubs are hauled, not by ponies, but by an electric locomotive.

FROM COAL FACE TO ITS DISTRIBUTING POINT

The advantages of electric power are fully realized, and a powerful electric fan keeps the air pure. Iron props are used to support the galleries. The artist has shown a concrete headgear frame replacing the older type of timber or steel. From the cage, coal goes to be unloaded and sorted.



TYPES OF LINING

Fig. 8. In this imaginary section of a shaft the types of lining used in various strata are illustrated, these being: (A) top soil, brick or concrete; (B) gravel and heavy ballast, concrete; (C) wet sand, tubbing—iron segments and concrete grouting; (D) marl, stone from lower strata; (E) sandstone, no lining; (F) hardstone, no lining, cracks filled with concrete or stone. The drawing is purely diagrammatic, as the strata would be much thicker than shown. It will be seen that lining a shaft is a considerable matter in view of the number of varied treatments which it entails. Channels placed at intervals collect water.

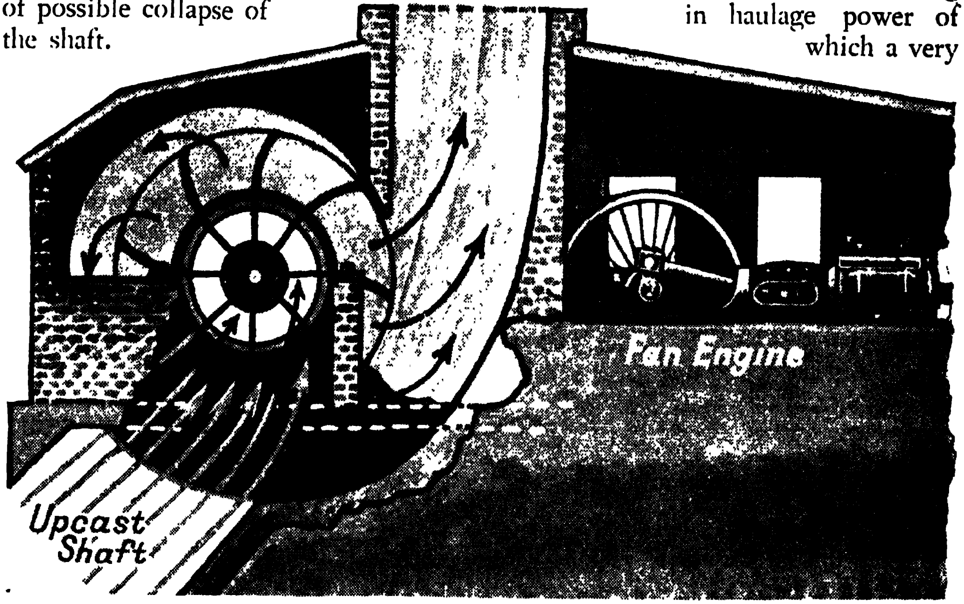
to the expense of sinking. Another method is to bore a number of holes surrounding the proposed shaft, then to drive 6-in. pipes into these, each one of which will have an inner pipe about 1½ in. in diameter. All these smaller pipes are connected up to a refrigerating plant, and for a month or so this will circulate a freezing mixture—generally magnesium chloride, that does not freeze at a higher temperature than about 22 degrees Fahrenheit, until the ground is frozen solid. The sinkers will soon get out the soft wet soil inside the frozen circle, and will be able to concrete a lining wall without fear of subsidence.

Each fathom—6 ft.—depth will cost, on the average, at least £250 for a shaft of 100 fathoms, and this is not an out-of-the-way figure. Small wonder, then, that the colliery company wants to be sure of getting a good seam at the bottom, for it is laid down by law that every colliery must have two shafts, both with winding gear, even if the gear is used only in one of them. One shaft is called the downcast, the other is the upcast; their other purpose will be seen presently. Fig. 7 shows the control room and electrical winding gear at a Sunderland colliery.

LINING THE SHAFT

Lining the shaft is a considerable matter, and different materials may be used according to the varying strata met with. Fig. 8 shows some of these, though it is merely diagrammatic as the strata would be much thicker than shown. Where hard stone is met, no lining need be put in, though cracks will be well filled with concrete or masonry. Wet strata will be lined with cast iron segments bolted together, with cement grouting pumped in all round. Brickwork will be used near the surface. Channels are formed at intervals to collect any water and prevent it from streaming down to the bottom of the shaft.

When the seam is finally reached, a series of radiating galleries, or passages, will be cut, but a thick column of coal will be left untouched except for these passages at the bottom of the shaft. In this way the risk of subsidence and earthquake effects on the colliery buildings at the surface will be obviated, not to speak of possible collapse of the shaft.



POWERFUL FANS DRAW BAD AIR FROM THE MINE

Fig. 9. The bad air which is drawn from the mine is thrown out by paddles into a spiral fan casing, part of which is broken away in the drawing to show the direction of the air outflow.

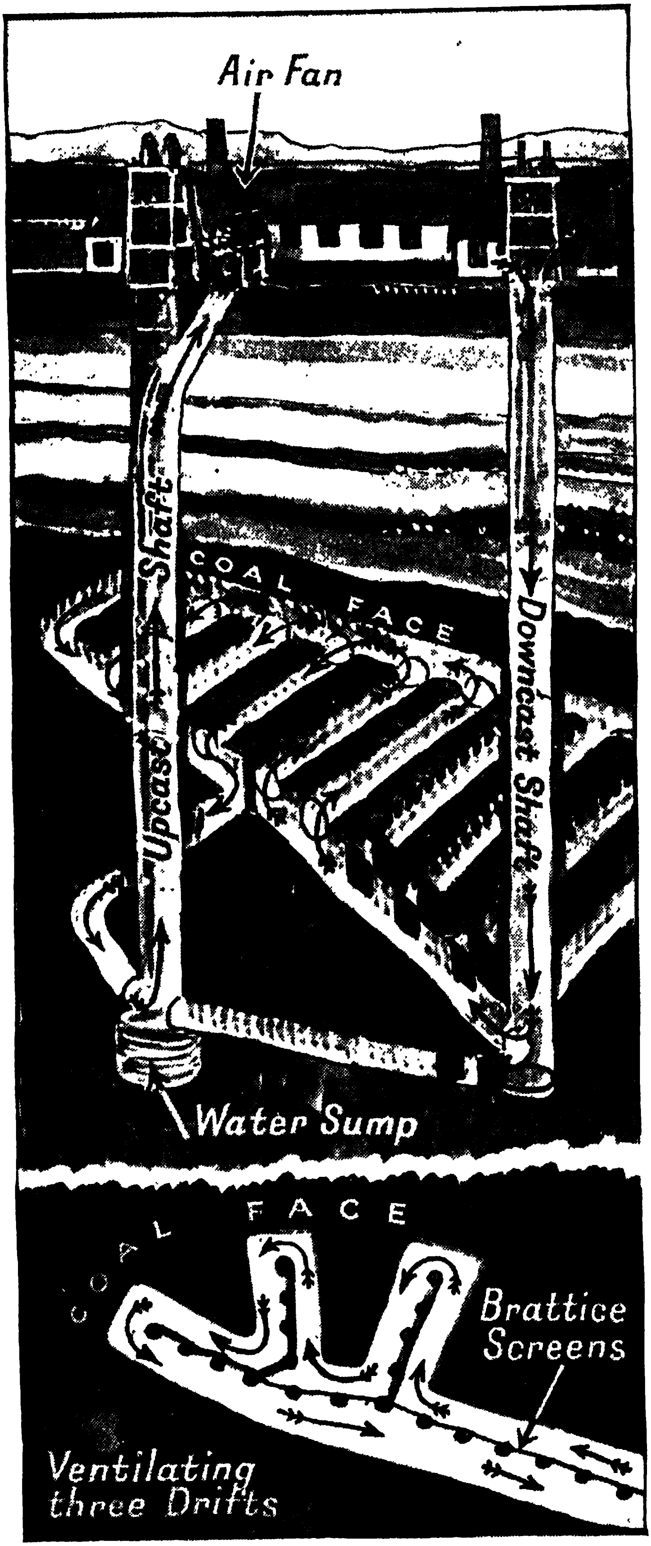
But not all of the galleries will be used as main roads, however; there will be two of these at least, for hauling out the coal and for the men to get to and from their work at the coal face.

Before there is any question of work down below, two things have got to be worked out in detail, first, ventilation, and second, de-watering. The bottom of the shaft, if it is the lowest point in the mine, will quickly fill with water, even in the driest situation; powerful pumps have to be put in, working continuously during the life of the colliery to bring this water to the surface and dispose of it to a safe distance. For this reason, a deep sump is formed below the staging, into which the water can drain; this sump will be the lowest level in all the workings, which as far as possible will be run upwards from the shaft bottom.

The purpose of this is twofold. First. as we have seen, to drain the water to the sump for its easy removal; second, provide a downhill run for the laden trams, so economizing in haulage power of which a very considerable saving is, in fact, made.

Conditions vary, of course, but there are few mines out of which water does not have to be pumped, amounting to several times the tonnage of coal hauled to the surface. At Tilmanstone Colliery, in Kent, for every ton of coal raised 20 tons of water have to be pumped out, and eight tons of air circulated for ventilation. And as we have read, the pumps must be at work from the time the mine shaft sinking is begun until the pit is finally abandoned as worked out.

Ventilation is the next great problem; possibly several thousand men may be down below, along with animals also in some places, and every one of them must

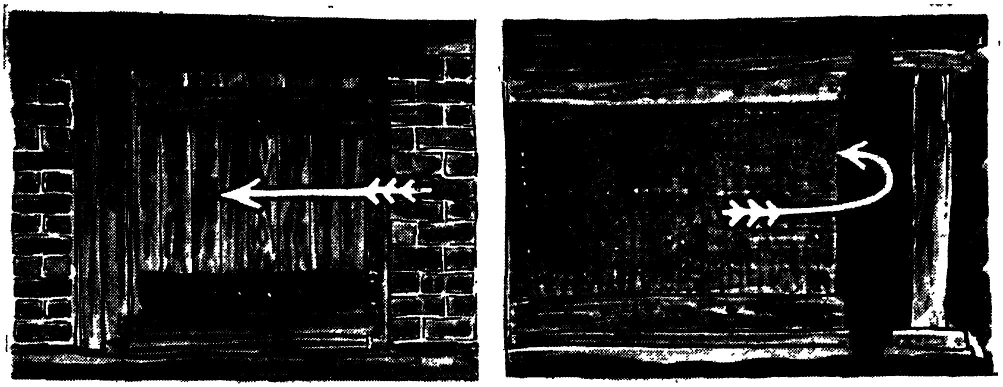


have adequate supplies of air. It gets very hot indeed down there, and in any case a man engaged in the hard labour of coal-getting gives off a great deal of heat himself. Something like 100 cub. ft. of fresh air every minute ought to be provided for every man in the pit, apart from the air that is wanted to clear away all the foul gas given out by the coal itself, about which more will be said later.

We now come to the shafts again. At the top of the upcast shaft powerful fans are at work, drawing air out of the mine, and to replace this, equal quantities flow down the other shaft. Fig. 9 shows such a fan and its engine. Both shafts are connected by a road, and to prevent the air flowing straight through without flowing through the galleries, a scheme of curtains and doors has to be devised, by means of which short cuts for the air flow can be prevented. Fig. 10 shows on a small scale how this is done, and a typical door is also illustrated in Fig. 11. Some of the doors have shutters that can be adjusted to control the amount of air that enters what may be just a small working. Every place must have its

A VENTILATING SYSTEM

Fig. 10. A section of workings in which the circulation of air is shown by arrows. Entering through the downcast shaft, it is kept in motion by the fan at the top of the upcast shaft through which the air leaves the mine.



DIRECTING THE AIR FLOW THROUGH THE MINE

Fig. 11. It is important that the air flowing through the mine should not take short cuts, and a system of doors and screens directs the air to every hole and corner. The drawing shows one of the trapdoors which are kept closed by the pressure of air, and (*right*) brattice cloth screen.

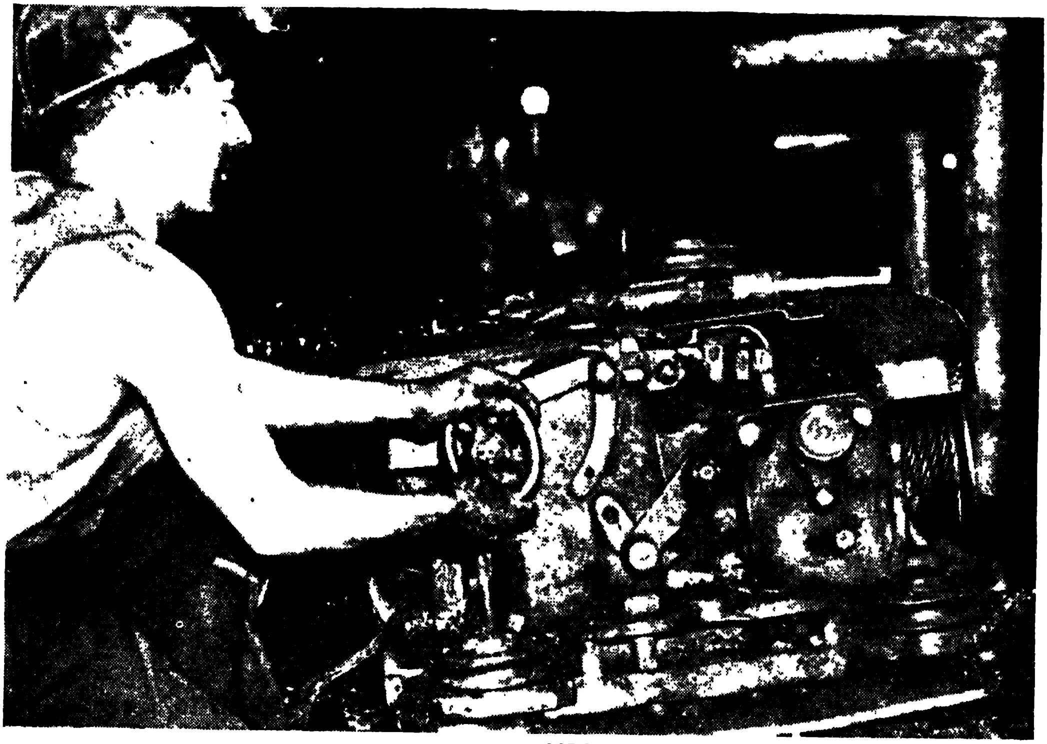
proper quantity, for any unventilated hole or corner means an accumulation of foul gas that forebodes an explosion.

Doors are always in pairs, one of which will be shut while the other is open; in this way an air-lock is formed, so that no disturbance of the main air stream is caused when men are passing through. Screens of a rough canvas, called brattice, are used to deflect the stream into closed workings, or drifts, as shown at the bottom of Fig. 10.

Almost every mine is dangerous as far as gas is concerned, though some are not. In the crannies of the coal seam the gas, which is mostly methane, very explosive when mixed with air, accumulates. Miners can often hear it hissing out, when a stroke of the pick opens up one of the crevices where a quantity has gathered. This is the dreaded fire-damp, against which constant vigilance has to be maintained, lest a chance spark should set off an explosion. This is not quite the right word for what actually happens. It is a very sudden burning, but the result is disastrous because all of a sudden all the air in the mine has gone, converted into asphyxiating gases—carbon dioxide, monoxide, and nitrogen. What is more, the ventilating screens may be completely destroyed, so making the work of the big fans at the top of the mine useless. They cannot draw the foul after-damp out until the screens can be replaced by men wearing oxygen masks.

In order to reduce to the absolute minimum any possibility of such disaster, no apparatus that might produce a spark is allowed down below unless it is very completely shrouded. Illumination is almost entirely limited to the dim glow produced by the safety lamp. Fig. 12 shows this lamp and the essential features of its construction.

The flame from an oil-fed wick is enclosed within a glass cylinder, surmounted by three cones of copper gauze, through which the necessary air supply for the flame must pass. This passage keeps the gauze cool, which introduces the main principle of the lamp, namely, that a flame is unable to pass through a cold gauze. So, if the atmosphere outside the lamp is dangerously charged with gas, and this gas is being drawn in, it will take fire inside the glass. No harm is done by this, on the contrary, the miner gets a clear warning as to the state of the atmosphere in which he is working. It is impossible for the miner to open the lamp and expose the flame because it is locked by an iron bolt that only a powerful magnet can move.

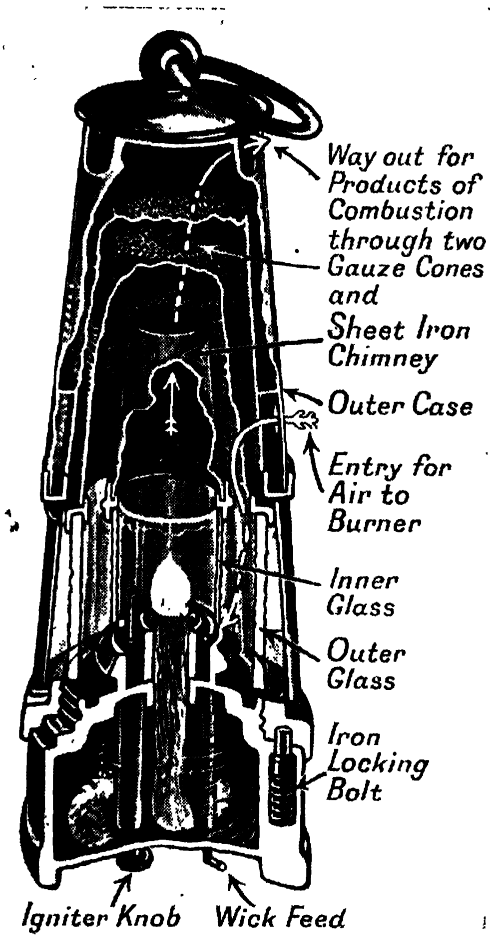


MECHANICAL DEVICES AND SCIENTIFIC

The photograph above shows a miner in a Midland colliery working a coal cutter, and that below the type of electric locomotive used to haul trains of loaded pit trucks to the shaft bottom.

APPARATUS SUPPLEMENT PICK AND SHOVEL

The traditional miner's equipment consists of picks for coal and stone, shovel, wedges and hammers. He also has tools for cutting holes for explosives and so on. The attack on the coal face may be conducted either by the miner with his pick, as seen above, or by the mechanical coal cutter. This quickly hollows out a deep groove in the coal so that a large block is hanging from the roof. To fetch this down an explosive and electric fuse are inserted at the top. When the charges are fired a large mass of coal comes down and it only remains for it to be loaded into the tubs and cleared away. Up-to-date oxygen apparatus is provided for protection against contaminated air and the illustration at left shows Durham miners, equipped with respirators strengthening a collapse in one of the galleries. Dangers and discomforts have not been altogether banished nor indeed can they be entirely eliminated from all mines, but as much as possible is being done to guard against and to minimize them.



A MODERN TYPE OF SAFETY LAMP

Fig. 12. This is made on the original Davy principle. Flame is unable to pass through the gauze, and thus dangerous gases burn inside the lamp only, and in this way are rendered harmless.

Other types of safety lamps have been produced, with a view to improving the illumination, but they are expensive compared with the original Davy type. Both of these are electric lamps; one, fairly often seen, has an accumulator in the base that goes on charge when the miner comes off his shift. The other uses a small quantity of compressed air to drive a little turbine, that in its turn drives a dynamo, supplying current for a small lamp. A pretty device, of course, but it can only work while near a supply of compressed air, and cannot light the miner's way to and from his work. Fig. 13 shows some details of these lamps and their very compact apparatus.

The miners in some pits have little battery lamps fastened to their caps, these give a good light in a limited sort of a fashion. It is worth noting that even today, the homely candle can also be seen, but this only in mines where no gas is ever known.

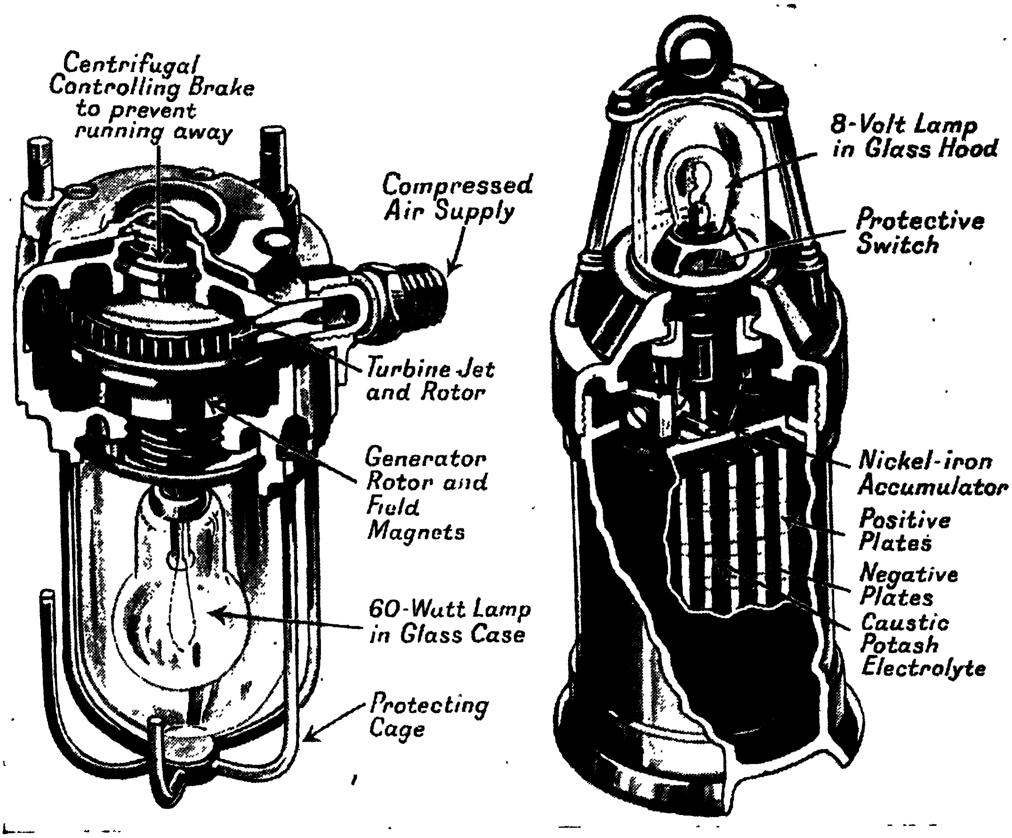
EXPLOSION AND OTHER DANGERS

Gas is not the only possible cause of explosions in mines, however. The large quantities of coal dust, of the finest description, that are always present everywhere in the workings are a source of great danger, or would be if fine stone dust were not sprinkled everywhere to neutralize the danger. Many fine dusts, such as flour, and others, have caused disastrous explosions when accidentally ignited, but stone dust is inert in this respect, and so it is used in hundreds of tons as a safeguard.

METHODS OF WORKING

It is the duty of an official, known as a deputy, to go through the workings at frequent intervals, on the lookout for trouble. It is his work to discover accumulations of gas, bad patches in the roofs, faulty timbering and the like, and generally to see to it that the mine is as safe to work in as it can be made.

Coal mines are worked on two systems as to getting the coal out from the seam. A large block is left around the two shafts, extending outwards for some distance, which depends much upon the depth of the mine. For instance, a depth of 70 fathoms would mean a bottom pillar at least 50 yd. square, but in any case it would extend far enough to support the buildings above. From the shaft bottoms, the workings are laid out in squares so that galleries are as far as



ELECTRIC LAMPS IMPROVE ON THE ORIGINAL DAVY MODEL

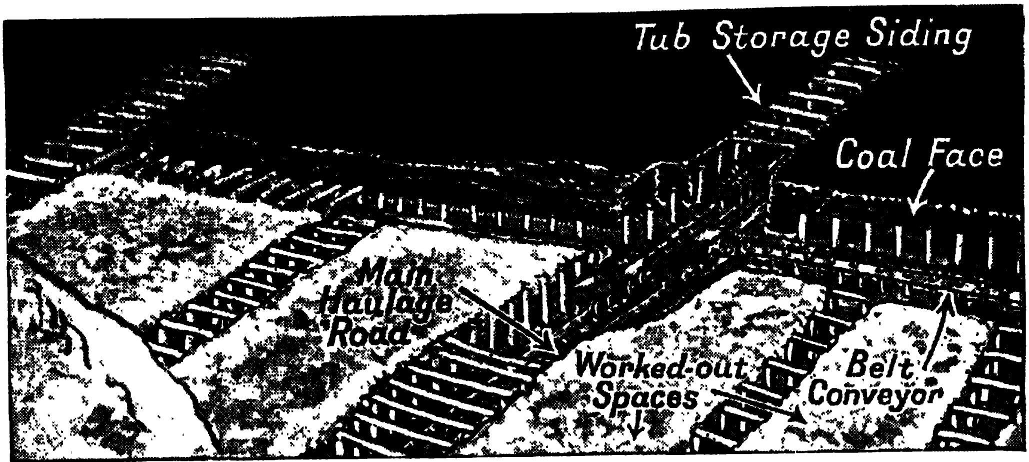
Fig. 13. Electric lamps are used in the mine. The lamp (*left*) generates its own alternating current supply, only requiring compressed air to work its turbine, which runs at 6,000 revs. per minute. A nickel-iron type of accumulator provides current for the lamp (*right*). Both lamps have automatic cut-out switches which operate if the glass hoods are broken. They give improved illumination.

possible at right angles, but this largely depends on the run of the seam.

The main levels, along which the won coal is brought "outbye," ought to be at least 11 ft. wide and $5\frac{1}{2}$ ft. high, and the branch roads 7 ft. wide. The former would have two tram tracks, and the latter, one, and their walls would be built up of packed stone at least 6 ft. thick, reinforced with some timber, supporting the roof beams that keep the huge weight of the strata above from breaking it in. Steel props and roof girders are frequently seen nowadays, as is electric light along the main roads.

Attacking the seam itself is the main object, and the method of doing this is either by longwall, or pillar and stall, or perhaps both. The nature and thickness of the seam is the principal deciding factor in the choice of method employed.

Briefly, the first system consists in attacking the whole width of the seam, working outwards, and supporting the roof in the rear with stone and waste rock taken out at the face (Fig. 14). This space at the rear is called the goaf, and the enormous pressure due to the weight of the strata above would smash the roof in unless it were well supported at once. Temporary supports of timber, or in some pits, steel, are used, but as soon as any accumulation of rubbish is available, great columns of it are stacked up and



LONGWALLING—WORKING THE WHOLE WIDTH OF THE SEAM

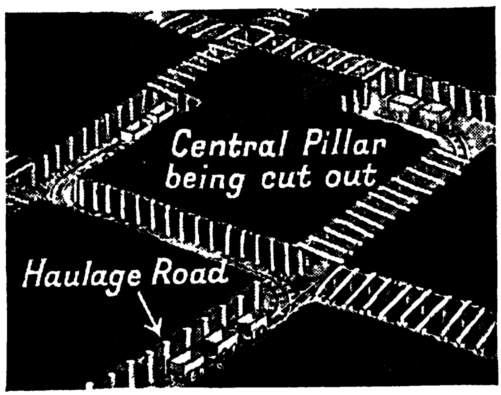
Fig. 14. Longwalling means that the whole width of seam is attacked, working outwards, and leaving a space at the rear which is called the goaf. Strong supports must be provided otherwise the weight of strata above would smash in the roof. Temporary props of timber or sometimes steel are erected, but piles of stone rubbish are used for permanent support. Chocks, or stacks of timber are often used at the main roads, being systematically arranged so as to allow as much space for movement as possible. At the coal face the miner may do his own timbering, using steel props which have a pointed end or wood props with a lid which serves to spread the support.

ROOF SUPPORTED BY STEEL ARCH

Fig. 15. A means of securing a permanent road is to brick up the walls and span the roof with steel girders or by steel arches, as shown above. When a seam is worked out the props can be taken away and the space can be filled up.

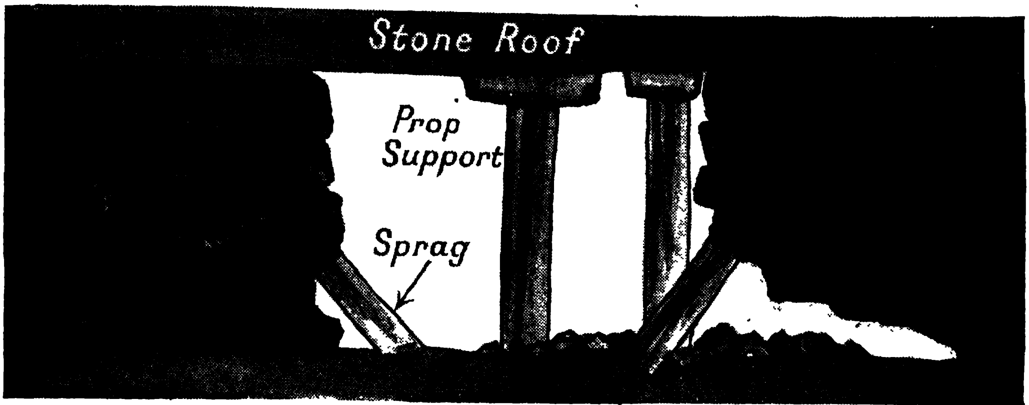
wedged together to give more or less permanent support. Chocks, which are stacks of timber laid criss-cross, are often used at the main roads, and here systematic timbering will be seen, the supports being spaced evenly, giving as much space for movement as possible. At the coal face the miner probably does his own timbering, using either steel props with one end pointed, or wood props with a wedged sole piece, or lid, to spread the support over a good area.

Where there is a permanent road to secure, the walls may be bricked up with steel girders to span the roofs, or steel arches, as in Fig. 15, may be used. When a seam is worked out and there is no

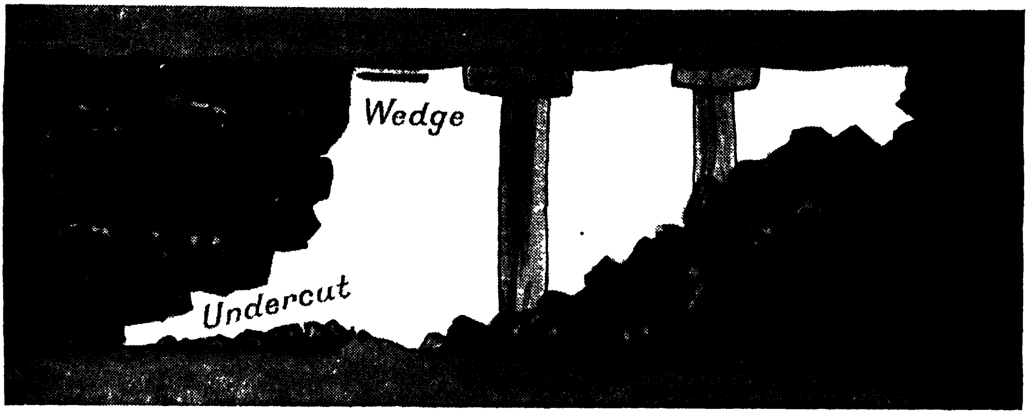


THE PILLAR AND STALL METHOD

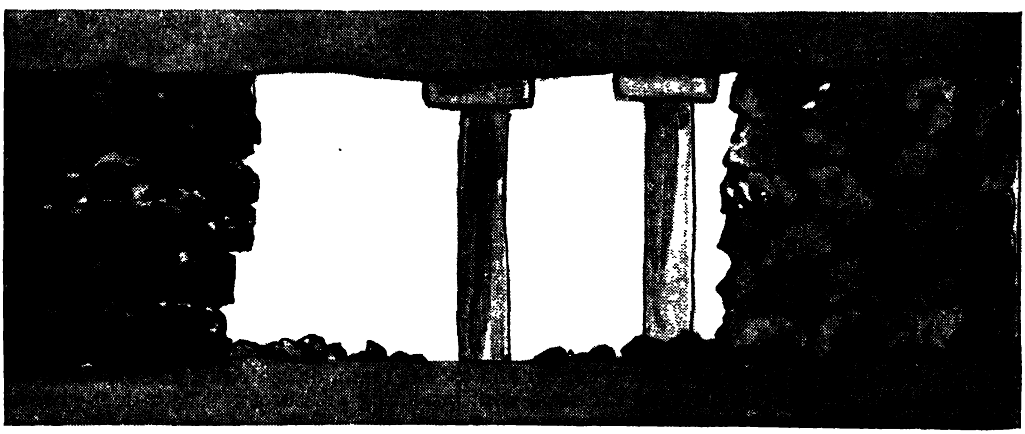
Fig. 16. The pillar and stall method consists in cutting roads through the coal, dividing it into a number of blocks or stalls and working round the outer edges towards a central pillar. As the coal is removed temporary support is put in but when a stall is cleared the roof may be allowed to collapse into the space cleared.



SEAM TO BE ATTACKED SEAM UNDERCUT

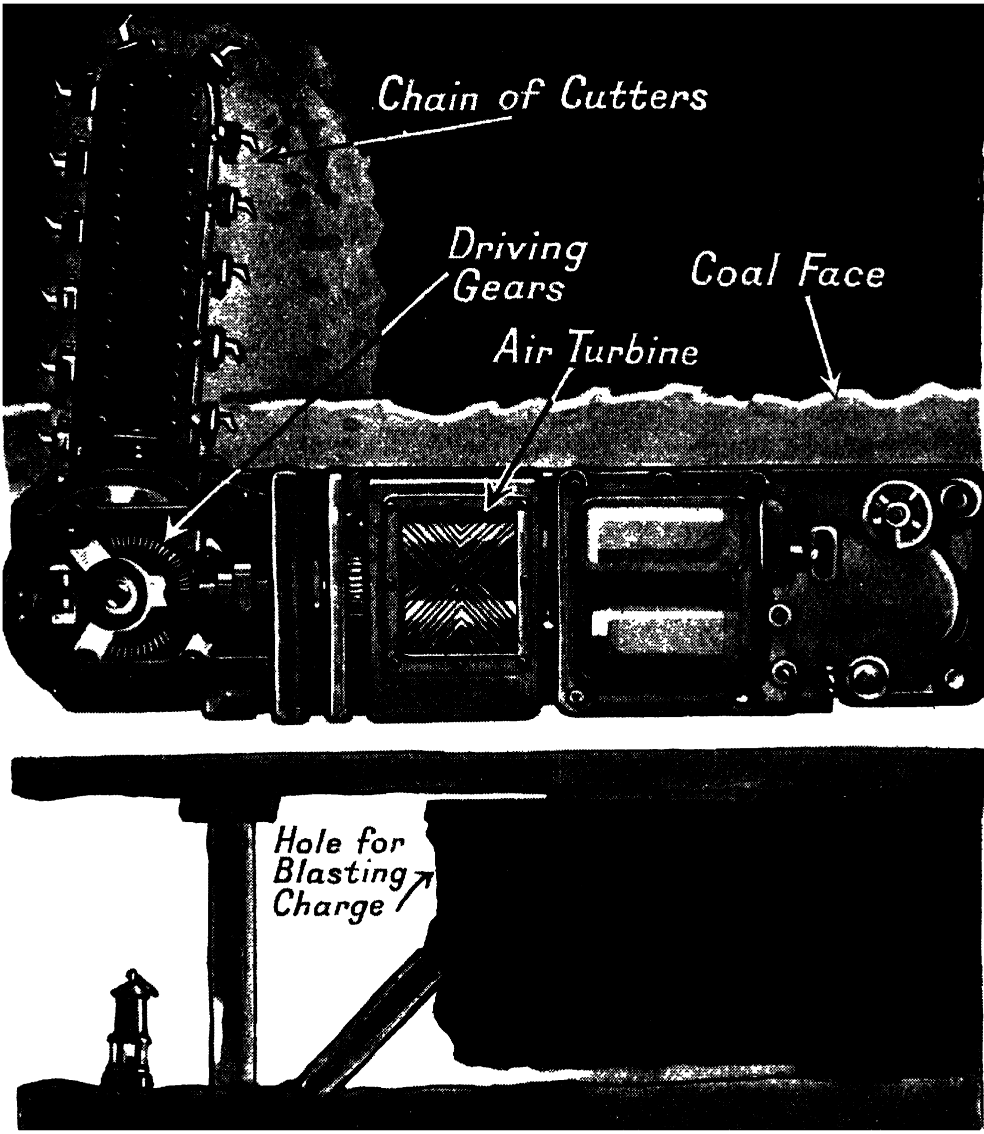


(*Above*) COAL BROUGHT DOWN BY WEDGE. (*Below*) RUBBLE REPLACING SEAM



STAGES BY WHICH THE COAL IS BROUGHT AWAY FROM THE SEAM

Fig. 17. The process known as undercutting is illustrated in this series of drawings; different stages being shown to left and right of the central pillar. At left in the first picture is the seam to be attacked. At right is the groove undercut beneath the seam. Next a wedge is introduced near the roof and thus a mass of coal is brought down as shown in the centre picture. All that is then necessary is to load the coal into tubs which return to the shaft. The last picture shows the section cleared of coal, and stone rubbish built up to support the roof and replace the original seam. Undercutting may be done by the miner with his pick or by the electric or air-driven coal cutter. The plan of a coal cutter with air turbine is illustrated on the following page.



THE COAL CUTTER AND ITS WORK

Fig. 18. Above is a plan of an air-driven machine with some of the gear covers removed, and below is the undercut made by the coal cutter. The cutting teeth, driven on an endless chain, are fed up to the coal at the bottom of the seam with increasing pressure, cutting a deep groove.

more need for keeping it open, props can be removed and the roof allowed to collapse, thus filling up the space.

Longwalling is a good system, enabling a large number of men to be employed, and permitting cutting machines to work with the maximum effectiveness.

The pillar and stall method consists in cutting roads through the coal, dividing it up into a number of large supporting blocks or stalls, and attacking these. Fig. 16 illustrates this. As the coal is got out, temporary support is put in, but when a stall is cleared, the roof may

be allowed to collapse into the space.

As to the methods employed in getting the coal away, these would be much the same in either method. The miners' tools consist of picks for coal and stone, shovel, wedges and hammers, tools for cutting holes for explosives and so on. Fig. 17 shows the process in successive stages. The idea generally is to undercut the coal at the bottom of the seam, and then to bring it down by its own weight, if possible; if this fails, then wedges will be tried, or perhaps a small charge of explosive. The undercutting may be done by the miner with his pick, or else it may be by machines, one of which is illustrated in Fig. 18.

An endless chain, to the links of which cutting teeth are fixed, is driven by electric motor or compressed air turbine. The teeth on the chain are brought into contact with the coal at the bottom of the seam, and being fed up to it with increasing pressure, they quickly cut a narrow groove in it. This groove soon deepens, and by the time the limit of the machine is reached, extends some way in, so that a large block of the coal is hanging from the roof. To fetch this down, holes are drilled at the top, into which an explosive charge is inserted, together with an electric fuse. All the men being withdrawn to a safe distance, the charges are fired, and down comes a large mass of coal, which only needs to be loaded into the tubs to be cleared away.

ELECTRIC LOCOMOTIVES REPLACE PIT PONIES

Fig. 19. The pony is disappearing from the more modern pits, where the advantages of electric power are realized. The train of tubs of coal is hauled by an electric battery locomotive, as shown.

Alternatively, in a good pit, we may see a conveyor installed. This is an endless chain belt travelling on rollers, driven by motor. The coal is loaded on

to the belt and carried along to the nearest convenient point where the train of tubs will be waiting. These conveyors are easily moved into new positions and can be extended to keep pace with the men at the face, where extension of the tram tracks might not be so easy. Conveyors are shown in Fig. 14.

The explosives used in shot firing are of a different sort from those used elsewhere. It is essential that no flame should be set up when the detonation occurs, for obvious reasons, but all the same, many colliery disasters have been attributed to their use.

THE CONVEYOR

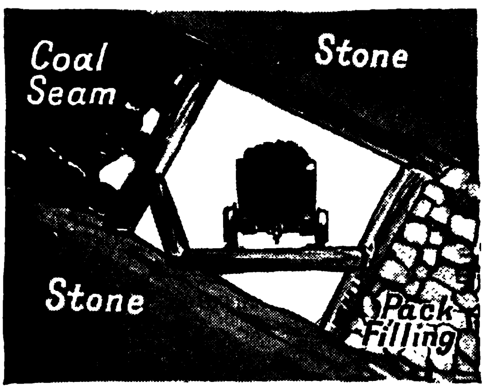
The conveyor, though it may be as much as 100 yd. in length, is used only to take the coal from the actual face to the nearest tram road. At this point it is raked off into a waiting tub, as the coal wagons are called. Tubs vary in capacity according to the depth of the seams in which they have to work, a common size would take about 6 cwt., and a large one about 15 cwt. Sidings have to be arranged for storage space for empties, so as to give a constant supply of tubs.

A train of tubs being ready, they are coupled together for haulage to the shaft bottom. This haulage is effected by pony, by endless rope, or by locomotive power. The pony is disappearing from the more modern pits, where the advantages of electric power are realized. The rope method provides a continuously moving rope, supported on rollers and pulleys carried on the floor, or in some cases on the roof. Clips and chains are provided by means of which the train of tubs can be attached to the rope and thus hauled along. A locomotive with a train of tubs is shown in Fig. 19. Powerful storage batteries provide the power for this machine, which has all its parts completely enclosed in flameproof casings to guard against fire due to the sparks that cannot always be avoided in making use of the electrical switchgear.

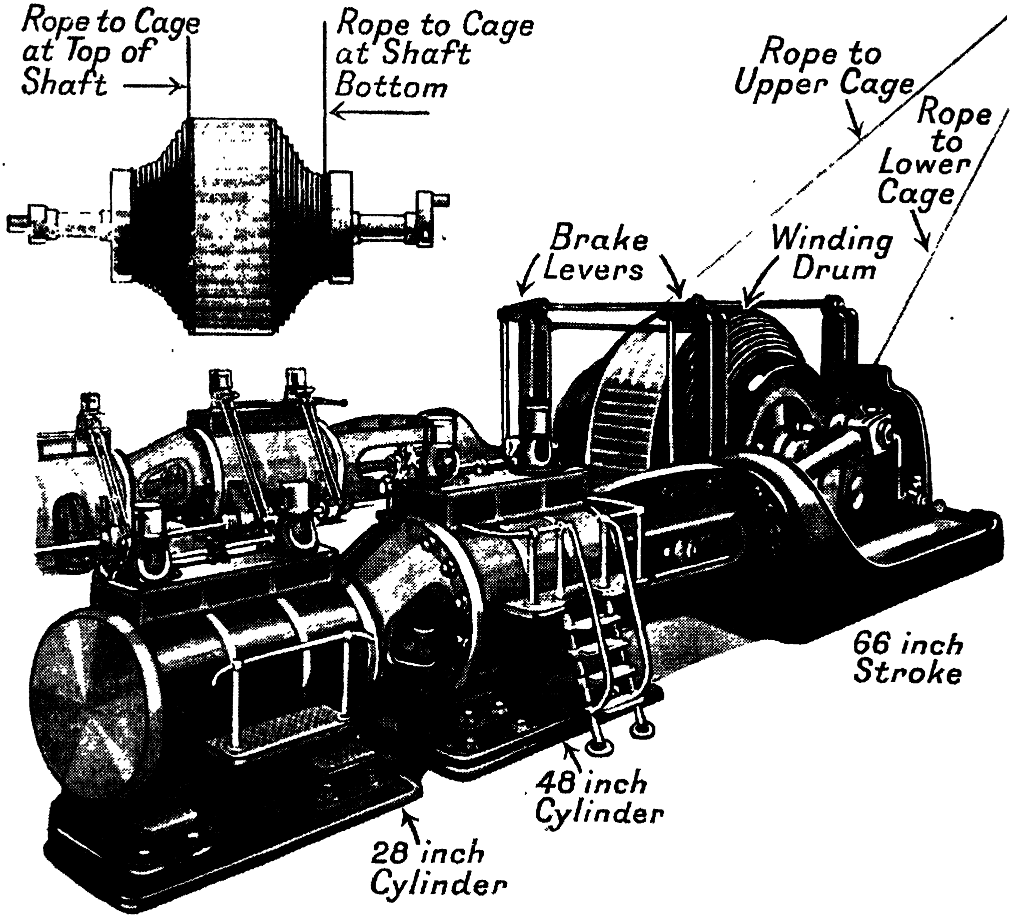
Signal wires are hung along the roads by means of which communication may be made with the man in charge of the haulage gear at the pit bottom; this is in case of derailment or other accident.

Bearing in mind our remarks at the outset about the distortion of the seams, and reference to Figs. 3 and 4, it must be realized that the seam very rarely lies flat and level. Not infrequently it runs very steeply upwards, making working difficult from all aspects. Fig. 20 shows what may have to be done in order to maintain the tram tracks on a level, or something like it. Not only must timber staging be built up, but if the seam is narrow, then a good deal of stone will have to be cut out of the roof and floor to provide headroom for passage along the road. Fig. 15 also shows where this has been done to provide for steel arch roof supports, a system much employed in some pits.

Arriving at the bottom of the shaft, the loaded tubs are run into the cage, which may have about four tons of coal on board when the signal is given to the banksman above by the onsetter below. Steam engines are the traditional source of winding power, but they are being replaced by electric motors in new pits



KEEPING TRAM TRACKS LEVEL
Fig. 20. Not all seams run horizontally. This shows how the tram road may have to be laid when the coal seam runs up at a steep angle



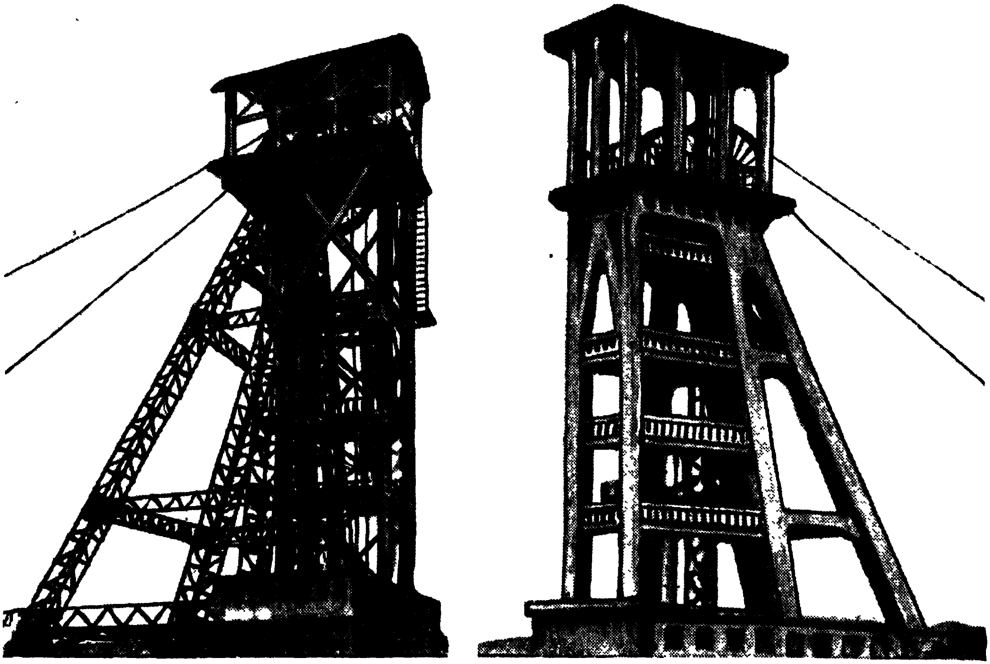
STEAM WINDING ENGINE PROVIDES POWER FOR HAULAGE

Fig. 21. The winding power for haulage between the bottom of the mine and surface is provided by a winding engine, driven either by steam or electricity. The drawing shows a double tandem steam winding engine developing over 2,000 h.p. Note the conical drum on which the rope is wound. By means of this device an increased leverage is given to the engine starting under load.

There are advantages on both sides. The disadvantage of the steam engine is in its waste of steam which must always be available. This is obviated to a considerable extent by the steam accumulator.

A big winding engine will develop anything up to 2,000 horse power, and the drum on which the rope is wound is of conical shape (Fig. 21). This device gives an increased leverage to the engine starting under load. Of course, there will be a cage descending with empty tubs at the same time as a loaded cage is coming up, which helps to counterbalance the load to some extent by its weight.

The ropes pass over huge pulleys, or sheaves, perhaps 20 ft. in diameter, at the top of the headgear frame (Fig. 22) the inevitable mark of the colliery. This frame may be built of heavy timber, as they all were at one time; or of steel lattice, the more usual form today; or in reinforced concrete as shown in the right-hand sketch. The lower part of the frame encloses the guides for the cage, and the staging at which loading and unloading is carried out, also. Here will be seen hundreds of tubs, full ones on



HEADGEAR FRAME—INEVITABLE MARK OF THE COLLIERY

Fig. 22. The ropes of the winding machinery pass over huge pulleys at the top of the headgear frame. Such frames were originally built of heavy timber, but today are usually of steel or reinforced concrete. The two types of headgear frame here shown, are: (*left*) of steel, and (*right*) of reinforced concrete. The lower part of the frame encloses the guides for the cage and also the staging at which hundreds of tubs are unloaded on to the screens, and empties await their turn to go below.

their way along to the screens, and empties waiting a turn to be sent below.

There are many safety devices incorporated into the winding gear, especially to guard against overwinding, but even so, the responsibility imposed upon the man in charge is considerable. The maximum number of winds per shift must be made, and this can only be effected if he is alert. Two thousand tons of coal in ten hours is a good shift.

The tubs of coal having arrived at the top, they are quickly run out of the cage, being pushed out by the empties that take their place. They are run out and tipped upside down over shaking screens that roughly grade their contents as to size, the holes in the screens are about 2 in. to 2½ in. across, so that all dust and small pieces fall through. The coal that remains passes on to a travelling belt conveyor, where all the shale and dirty coal can be seen easily and picked out.

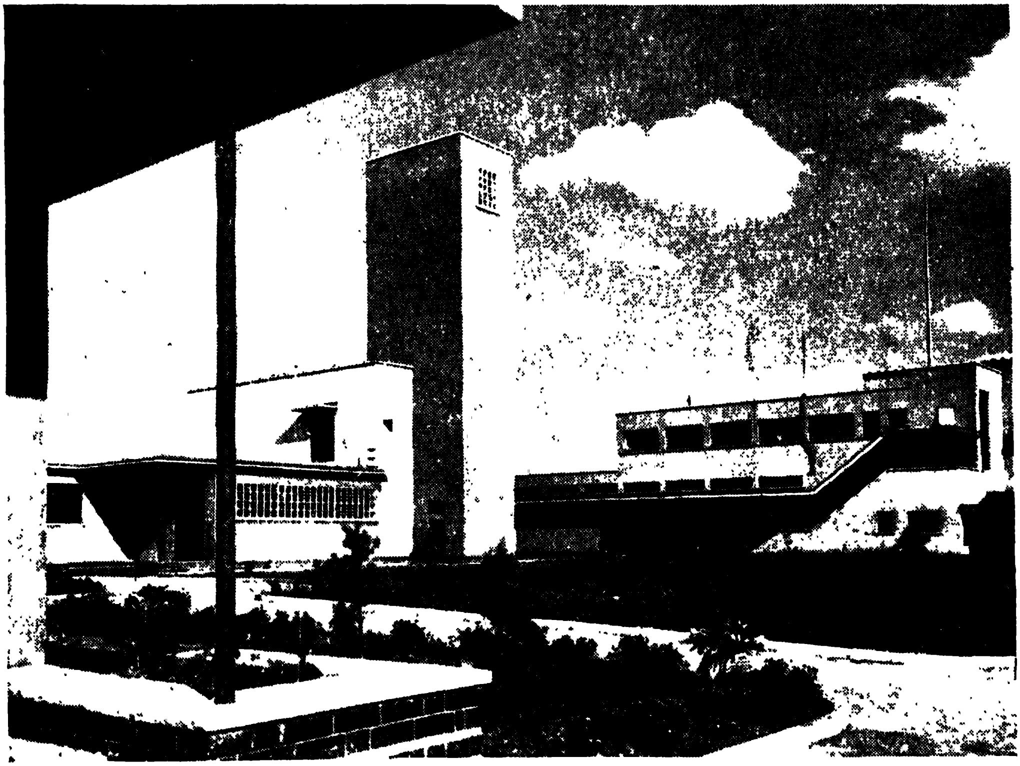
Shale is much heavier than coal, and advantage is taken of this fact to float the coal away with water. It is possible to pass the mixture into troughs where a carefully regulated stream of water actually floats away the coal and leaves the shale behind. If clean coal is wanted, it can be tested in a trough of a salt solution having a specific gravity of about 1.4, that is 40 per cent heavier than water, and everything that floats is good coal. There are other machines that can be used to sort out the waste, but the washing method is most used. One such device runs the coal down a spiral chute, the coal flies off the track, leaving the shaly stuff to slide safely to the bottom.

Any of the waste that can be used down below to make pack walls is returned there, but the remainder is gathered up by the travelling skips of a

rope conveyor, and carried off to be thrown on to an ever-increasing waste dump. These dumps are one of the almost inevitable adjuncts to every mine, and form a landmark almost as familiar as the headgear frames. Very little use has yet been found for this rubbish, but doubtless some day it will be turned to valuable account.

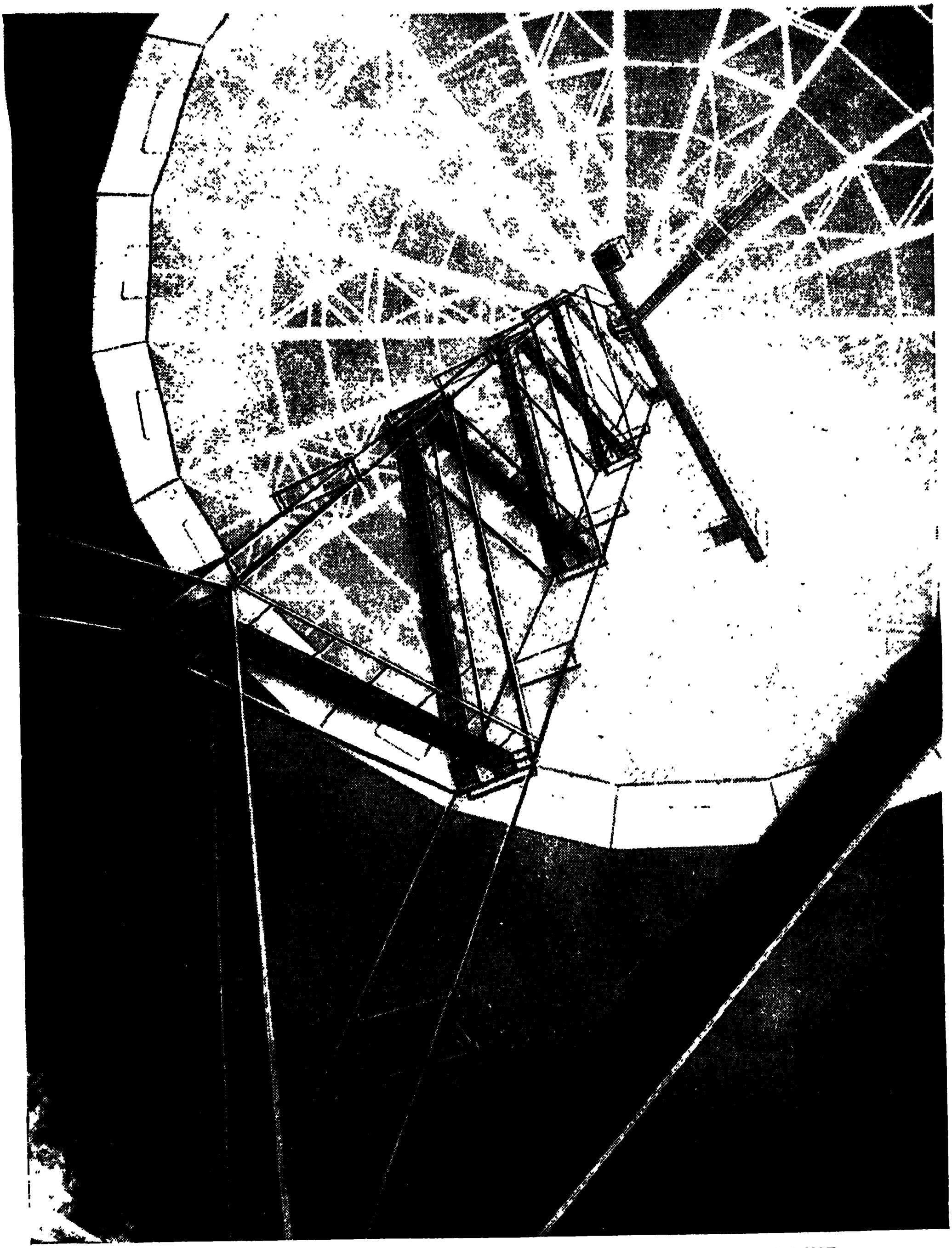
It may be of interest to record some of the depths of mines from which coal is won, both in Britain and elsewhere. Generally speaking, the deepest shafts are on the Continent, in Belgium, where at Flènu one pit is 3,773 ft. in depth. Some of the pits in Germany exceed 3,500 feet, but such depths are rather exceptional. Here in Britain 2,800 feet is reckoned deep, and the famous Barnsley seam is worked at that depth. Ashton Moss, Lancashire, exceeds this by 80 ft. Such depths as these add enormously to the cost of the coal won, and none but seams of a good thickness and extent would be worth the expense. The Barnsley seam is 7 ft. thick, and so justifies the depth. The miners in some parts of this pit have to travel more than two miles from the shaft to their work, but electrically hauled trains take them to and fro on this long journey.

Most people would think of coal first and foremost as a fuel, but it is very much more than that; man may well regret the terrible wasting of it that went on since its discovery and its early use entirely in that direction. There is not room here to detail the astounding list of substances that are to be obtained from coal, almost entirely without affecting its fuel value; some of these are dealt with in the following chapter.



MODERN PITHEAD BATHS

In fine modern buildings of the type illustrated above, the miners bath and change in comfort before going home. Such improvements add both to the well-being and efficiency of the worker.



WHAT THE INSIDE OF A WATERLESS GASHOLDER LOOKS LIKE

If you were to look up inside a waterless gasholder this is the perspective that would meet your eyes. The reservoirs of gas commonly, but incorrectly, known as gasometers, are properly called gasholders, since they store but do not measure the gas. There are four main types—guide-framed, spiral-guided, pressure and waterless. The waterless type consists of a cylinder in which a circular piston is free to rise and fall, its edges being kept gastight by a tar seal. The space above the piston is open to the atmosphere through vents, and access is obtained by means of a lift and down through the top by a ladder which folds as the piston rises. The above view is taken beneath ladder and upper platform. Gas is made at a steady rate, but as the demand varies storage is essential.

HOW DOMESTIC GAS IS PRODUCED AND SUPPLIED

The nature of gas. Its by-products. A tour of the gasworks. Methods of carbonization. The water gas plant. Types of gasholder—guide-framed, spiral guided, pressure and waterless. How gas is distributed. The coke grading plant. Wet and dry gas meters.

FROM a series of scientific discoveries quite unrelated to the thought of using gas as a fuel sprang the ultimate introduction of commercial gas into modern life. As long ago as in 1609 it was known that an inflammable air was produced when wood, peat, or coal was heated in an enclosed vessel, but the knowledge remained more of a scientific curiosity than of any practical value until 1792, when William Murdoch, following experiments made during his boyhood, lighted his home at Redruth, in Cornwall, by means of a home-made gas plant. Later, in 1801, he interested his Birmingham employers, Boulton and Watt, in his new scheme of lighting, and there constructed a gas plant to light their foundry. It is interesting to note that the Watt of this firm was James Watt of steam-engine fame. Thus were the pioneers of the practical uses of both steam and gas closely associated.

Six years later, in 1807, gas was used publicly for the first time when Pall Mall was lighted by a private company. In 1812 this London company was granted a Royal Charter. Its name subsequently became the Gas Light and Coke Company, which is today the largest gas undertaking in the world.

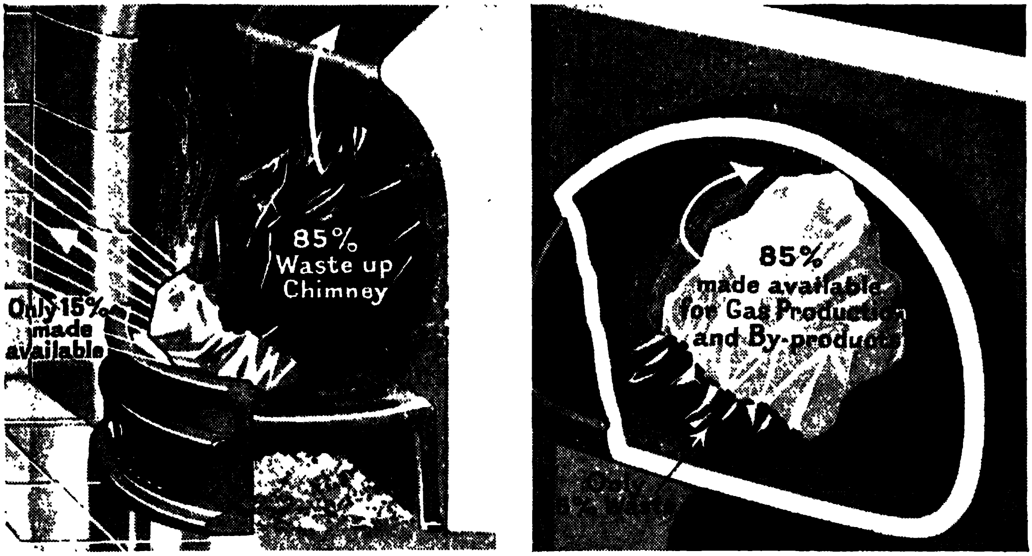
Although the greater part of the town gas, as it should be called to distinguish it from dentist's gas, war gas, and so on, used in Great Britain is made from coal, a fair proportion is made from oil and coke. It is not always correct, then, to call it coal gas. In America large quantities of natural gas are obtained at the oil wells, and this is used either by itself or mixed with manufactured gas. Natural gas is transported in pipe lines.

TOWN GAS

Town gas, as supplied in Great Britain, may differ from town to town according to the type of coal used and the method of manufacture. Very strict legislation exists with regard to the manufacture and supply of gas, however, and each gas undertaking must maintain the quality of its gas, the principal requirements relating to the heating value of the gas, the pressure at which it is supplied, and the removal of certain impurities.

Town gas is a mixture of gases—chiefly hydrogen and compounds of carbon and hydrogen. Irrespective of local variations, the constituent gases are the same, the only difference lying in the relative proportions.

The heat produced when town gas is burnt is due to the combustion of hydrogen and hydrocarbons combining with oxygen to form water vapour and carbon dioxide. Town gas cannot burn without oxygen, which is most readily obtained from the air surrounding the gas burner. The amount required is usually about five parts of air to one of gas, according

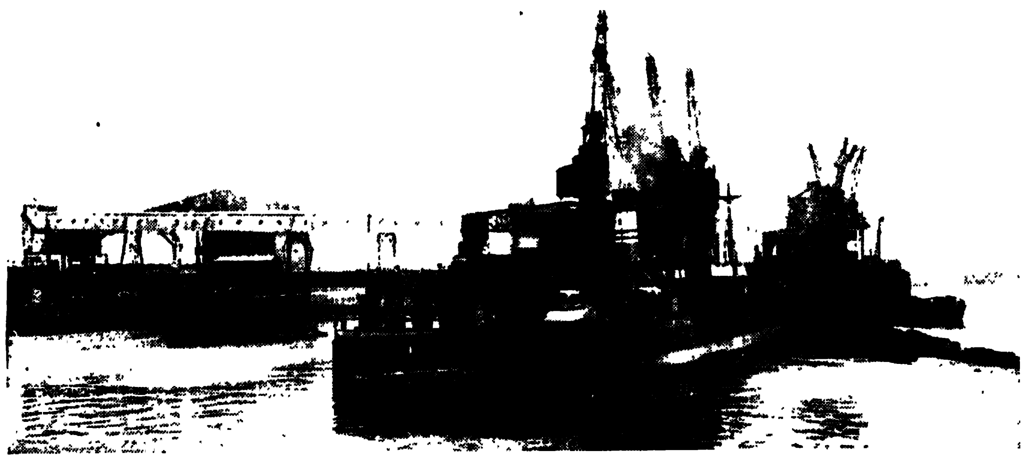


WHERE THE HEAT ENERGY FROM COAL GOES

Fig. 1. Where the heat energy from coal goes is strikingly illustrated in this diagram. In the domestic grate (*left*) only 15 per cent of the heat of the coal is made available. The gas works on the other hand, contrives to make available 85 per cent of the heat energy of the coal.

to its composition. This explains why gas holders (of which more will be said later) and gas mains cannot normally explode. They are filled with gas and no air is present. If a hole was made in one of them, gas would escape rather than would air enter and, if ignited, would merely burn in that case as it escaped into the atmosphere.

No matter what method of gas making is employed, coal forms the basis for all town gas production in Britain. Coal is



UNLOADING COAL AT A LARGE GAS WORKS

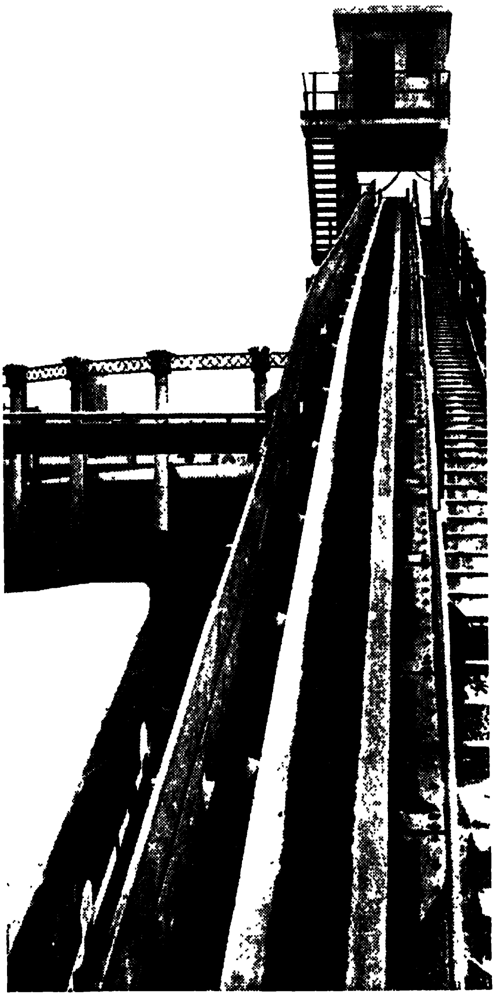
Fig. 2. Special handling plants are used for receiving the coal which is often sea-borne and two ships may be unloaded simultaneously at one such plant. From electrically operated travelling jib cranes coal is discharged via travelling hoppers (large containers) to conveyors, travelling bands of rubber which run along each arm of the pier and deliver their load to a larger conveyor.

not merely a fuel; it is the potential source of a great variety of important products. When raw coal is burnt in an ordinary fireplace all these by-products, as they are called, pass up the chimney and are lost while, incidentally, 75 per cent of the heat is dissipated as well. When coal is treated at the gas works, however, not only is the gas obtained, but also a host of products such as coke, tar, benzol and many others are made available. These main by-products in turn yield a tremendous number of other valuable constituents. Fig. 1 shows how little coal is wasted at the gas works compared with what happens when it is burnt in the grate.

One ton of coal treated at the gas works yields town gas and the following main by-products, the figures given showing a fair average result, though the actual quantities vary with the quality of coal used and the methods of gas manufacture employed: town gas, 72 therms or about 14,400 cub. ft.; coke and breeze, 14 cwt.; crude liquor, yielding sulphate and nitrate of ammonia, 15 gals. coal tar, 10 gals.; crude benzol, yielding benzene, toluene, solvent naphtha, etc., 2 gals. Retort carbon is also produced in small quantity.

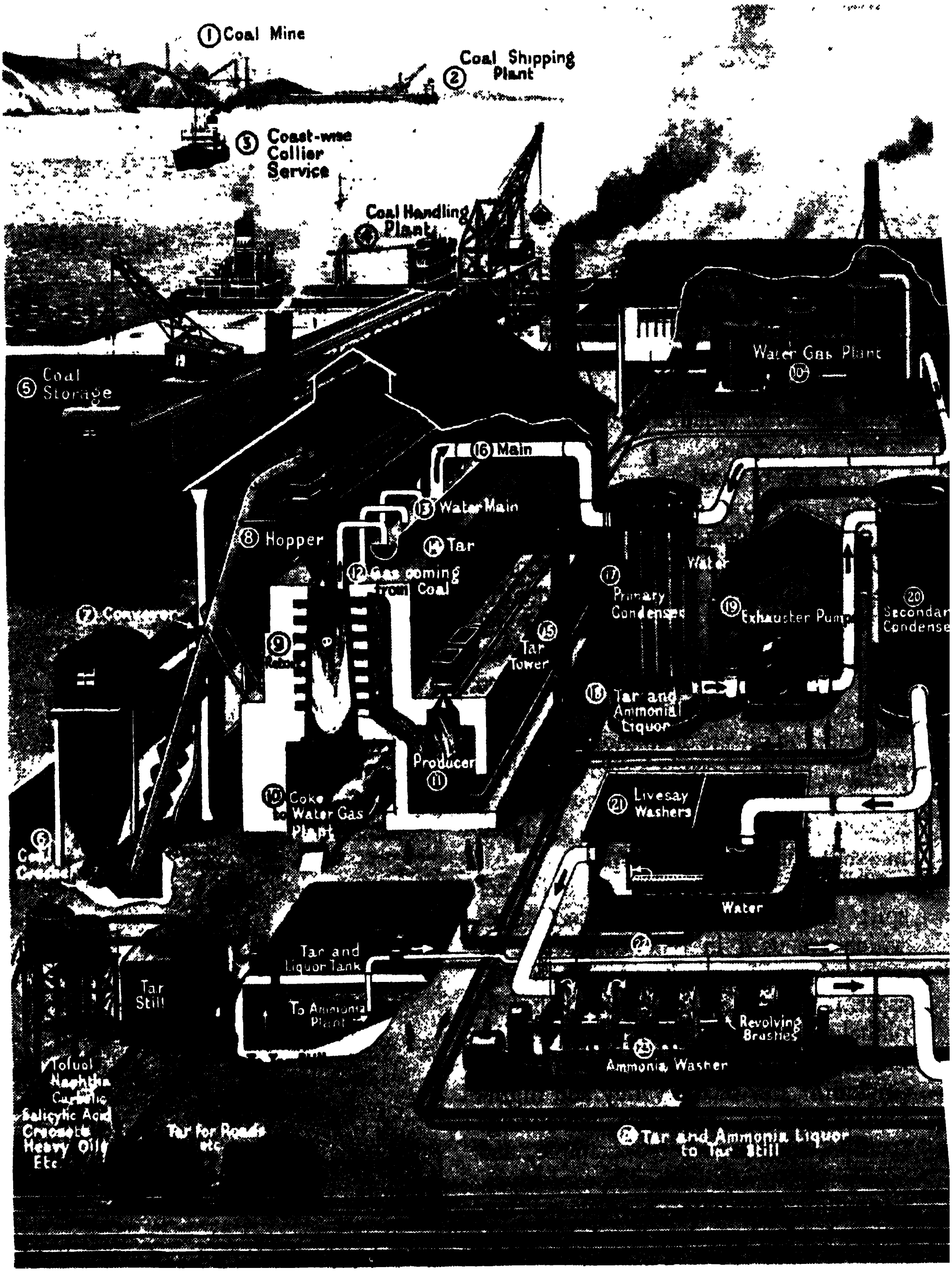
These main products are still further split into a number of derivatives which are used in the manufacture of many dyestuffs, medicines (including aspirin, phenacetin, ephedrine, phenolphthalein, and others), bactericides, disinfectants, a host of synthetic perfumes (including lily of the valley and night-scented stock), synthetic flavourings (vanilla, or almond, for example, and even peppermint), cosmetics, explosives, household ammonia, varnishers, lacquers, baking powder, freezing agents, smelling salts, and lead pencils.

There are many types of coal; each being suitable for a particular purpose. The coal used for making gas may be of several types according to the method of production employed. From the coal-fields the coal is either sea-borne or rail-borne to the various gas works all over the country. There it is unloaded by special handling plants. One such plant consists of eight electrically operated travelling jib cranes, which carry grabs each of 3½ tons capacity. Facilities exist for the simultaneous unloading of two



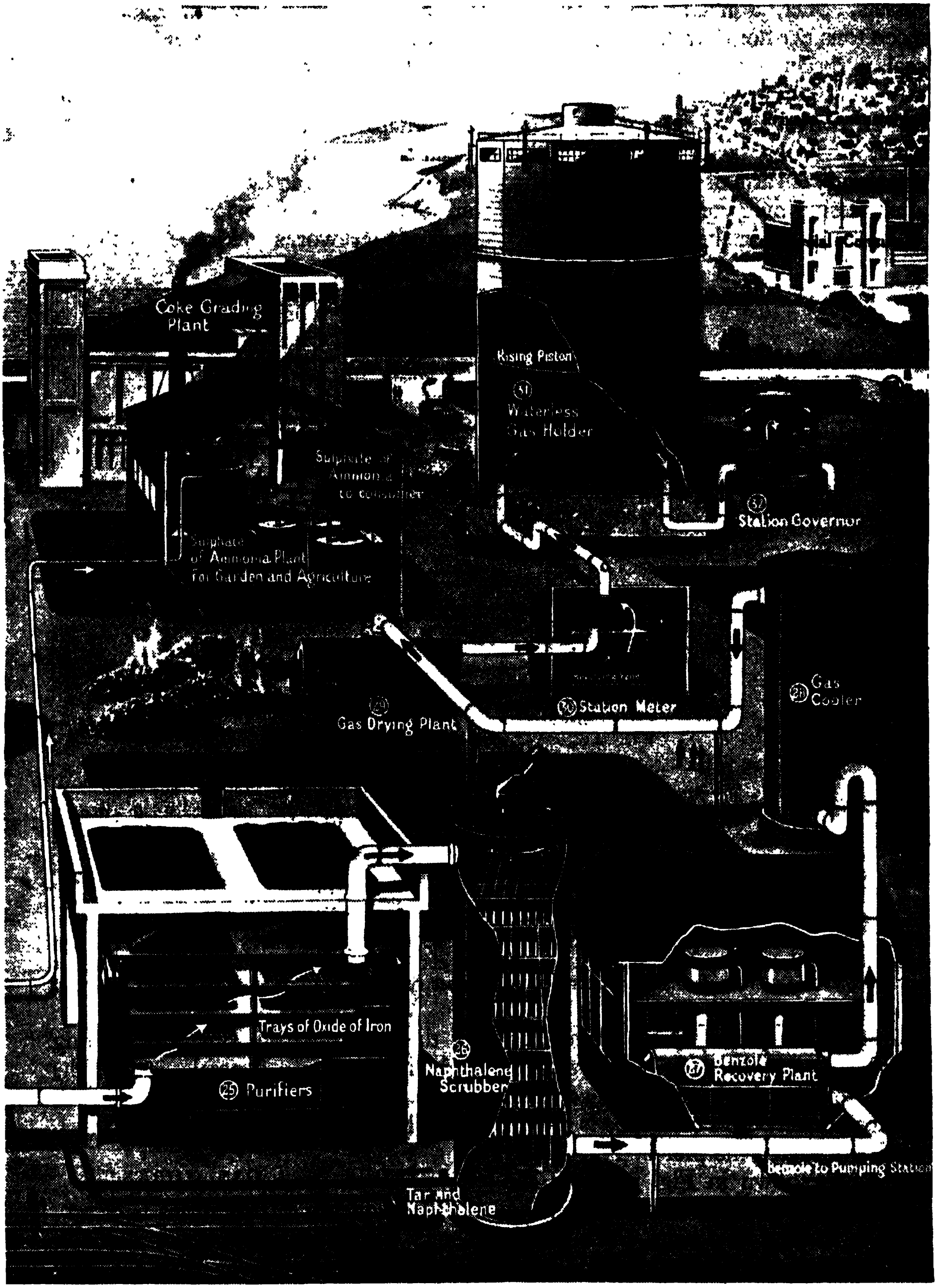
BELT CONVEYOR FOR MOVING COAL

Fig. 3. A belt conveyor for moving coal or coke about a gas works. It is a rubber belt running on rollers. Thousands of tons per hour can be moved in this way to the service bunkers, whence the coal is discharged into wagons.



FROM COAL MINE TO CONSUMER—

Fig. 4. The drawing shows at a glance the many stages which go to the production of gas: the direction of arrows indicating the lengthy journey from the arrival of coal at the handling plant



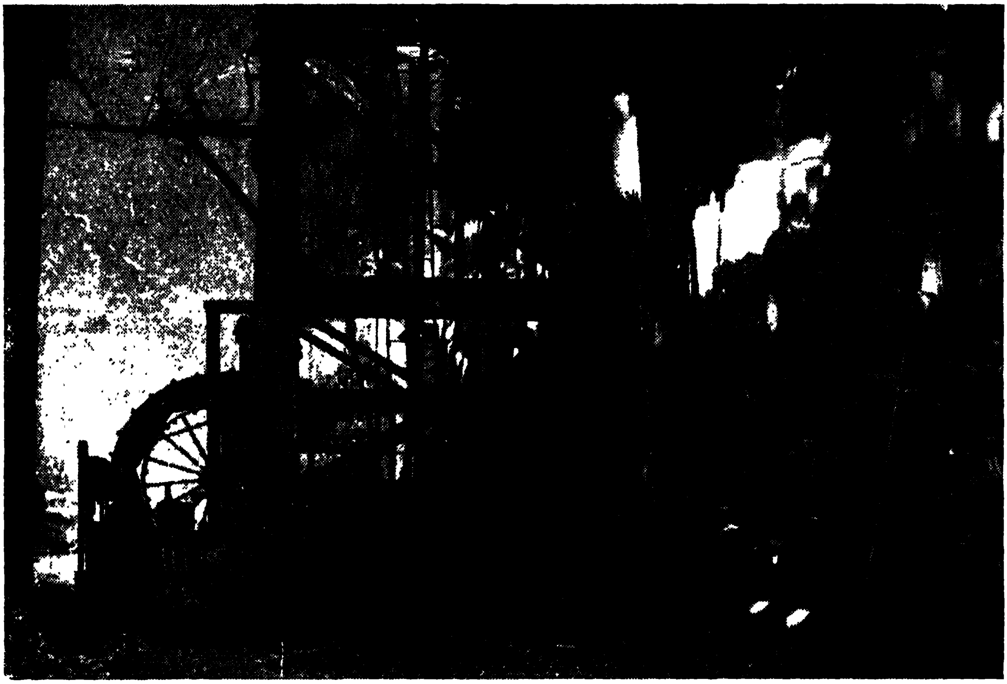
THE LAYOUT OF A GAS WORKS

to the combustion chamber, thence to the condensers; then through the purifying, cooling and drying processes, until storage in the gasholder. The numbered sequences are explained in text.

vessels, when a maximum output of 2,000 tons per hour can be reached. The coal is discharged from the cranes via travelling hoppers (large containers) on to belt conveyors, which are travelling bands of rubber 4 ft. wide and which run along each arm of the pier. The belts, after passing over continuous automatic weighers, meet in the centre of the pier

For gas works on river or canal banks the coal is transferred to barges, and on arrival at the works the same method of unloading is employed as from the sea.

Perhaps the best way for us to see what happens to the coal and how our gas and the coke and various by-products are obtained is to go for an imaginary tour of a gas works and inspect each part



CHARGING A RETORT WITH COAL—A LARRY IN ACTION

Fig. 5. Automatically charging a horizontal retort with coal by means of a larry is the process shown in the above illustration. A travelling larry pushes in about 18 cwt. of coal at one end and pushes out coke at the other. Horizontal retorts are the most common method used of baking the coal.

and deliver the coal on to a larger belt conveyor 4 ft. 6 in. wide, which takes it ashore to a 6,000-ton reinforced concrete service bunker. This conveyor is shown passing up from the pier in Fig. 2, and another is shown in Fig. 3. From the bunker the coal is discharged into 5-ton wagons, sixteen to a train, and six such trains can, if necessary, be loaded at once. The trains convey the coal to the various retort houses which constitute the first stage in the production of the gas.

of the plant in turn. But before doing this, let us take a general view of the works in order to get a broad outline of what happens at the various stages.

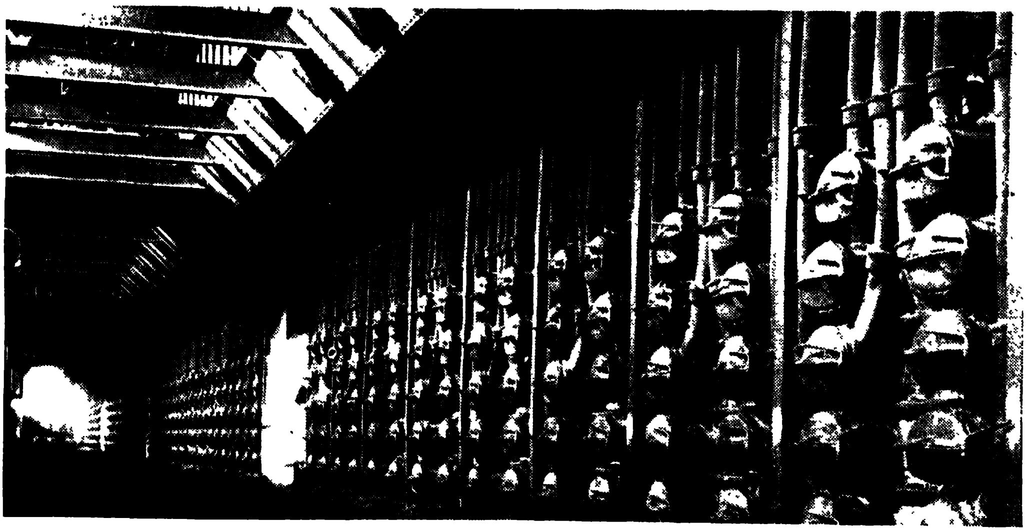
TOUR OF A GAS WORKS

The sequence of operations is clearly shown by the numbered descriptions in Fig. 4. From truck or boat the raw coal is stored as required until fed to a coal crusher (sequence 6), where it is broken down to a size suitable

WHITE-HOT COAL IN THE FURNACE

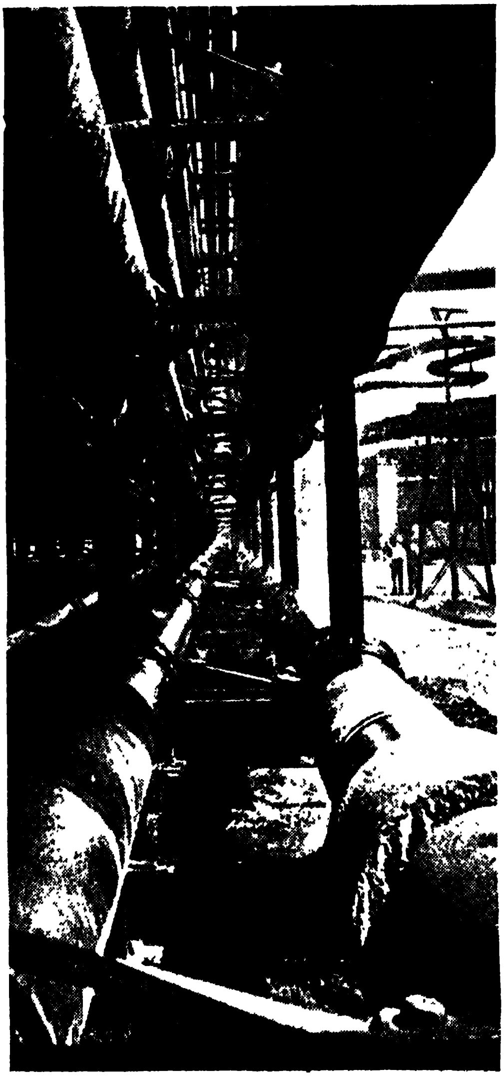
Fig. 6. A stoker is attending to a horizontal retort. The door on the left with the chain attached is the cover of the furnace for heating the ten retorts which are mounted above and are made of heat-resisting, refractory material. The open door shows the white-hot coal inside.

for the particular type of carbonization required. Carbonization is the term used by gas engineers to describe the process of baking or distilling the coal. It is conveyed (sequence 7) to overhead storage hoppers (8) in the retort house, and is then fed to the retorts (9), which are made of heat-resisting refractory material. Some of the coke (10) from these retorts passes to the water-gas plant (10A). The retorts are surrounded by a combustion chamber and are heated externally by gas made from coke in what are known as producers (11). The temperature of the coal is raised to around 1,800 degrees Fahrenheit.



WHAT A RETORT HOUSE LOOKS LIKE

Fig. 7. This is a general view of a large horizontal retort house, looking from the charging end. The retorts are built up in sets of from three to ten and there are over three hundred such settings in this particular works—making an imposing total of something like three thousand retorts.



CONDENSER PIPES

The crude gas passes through a water-cooled system of pipes. Tar and ammonial liquor are then condensed and run off into a tank.

The different forms of carbonization plant will be described later: for the moment we will try to get a bird's eye view of the general process. On being heated the coal gives off gases and tarry vapours and passes through what is termed a plastic range. From the retorts the gas and tarry vapours pass into a pipe known as the crude gas or foul main (16) where a certain amount of the tar condenses out of the gas (14 and 15). From the foul main the gas passes (16) to the primary condenser (17) where it is water-cooled and tar and ammonial liquor are condensed and run off to the tar and liquor tank. Water gas from the water-gas plant also passes to the primary condenser as shown. Next in line comes the exhauster pumps (19) which serve to extract gas from the retort and on its journey so far and then to pump it through the remaining parts of the plant and eventually into the gasholder.

PURIFYING STAGES

The gas now passes to the secondary condenser (20) after which come the Livesay washers (21) in which the gas bubbles through water to remove further tar and ammonial liquor (22), which also pass to the tar and liquor tank.

Next comes a different type of washer (23) whose main purpose is to remove the remainder of the ammonia. Again the residue (24) is run off to the tar and liquor tank. The gas now passes to the purifiers (25). Purification is the system of removing sulphuretted hydrogen from the gas. This is one of the legal obligations of gas undertakings.

Even so, we have by no means finished the gas treatment. The next operation is to remove the naphthalene by means of oil in the washers (26) from which the gas is passed on to the benzol recovery plant (27) which removes the benzol. After being cooled (28) and dried (29) the gas is measured by the station meter (30), so that a check can be made of the amount of gas produced and supplied. The reason for drying the gas is to remove the water vapour, and so to prevent water being deposited in the pipes in the streets and in people's houses. Finally, it enters the gasholder (31) where it is kept in readiness to be sent out to the consumers.

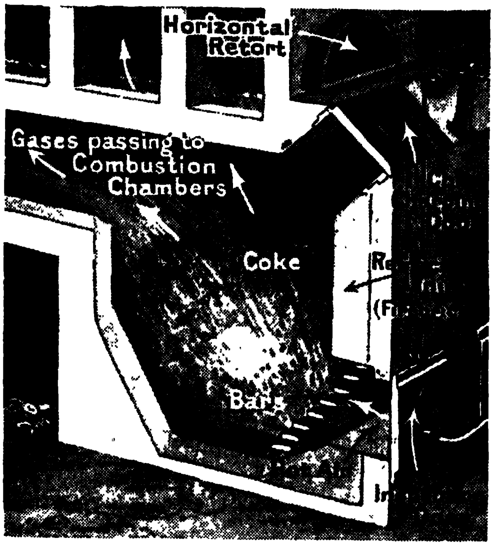
Having obtained a general idea of what goes on at a gas works, we will

DISCHARGING COKE FROM A HORIZONTAL RETORT

Fig. 8. Coal takes about twelve hours to become carbonized at the end of which time refuelling takes place and the hot coke which is being replaced by the coal is then guided away into a trough.

now look more closely at each part of the plant and the sequence of operation.

Horizontal retorts are the original and most common method of carbonization—of baking the coal. They are made mainly of silica in order to withstand the high temperatures set up, which are in the neighbourhood of 1,350 degrees

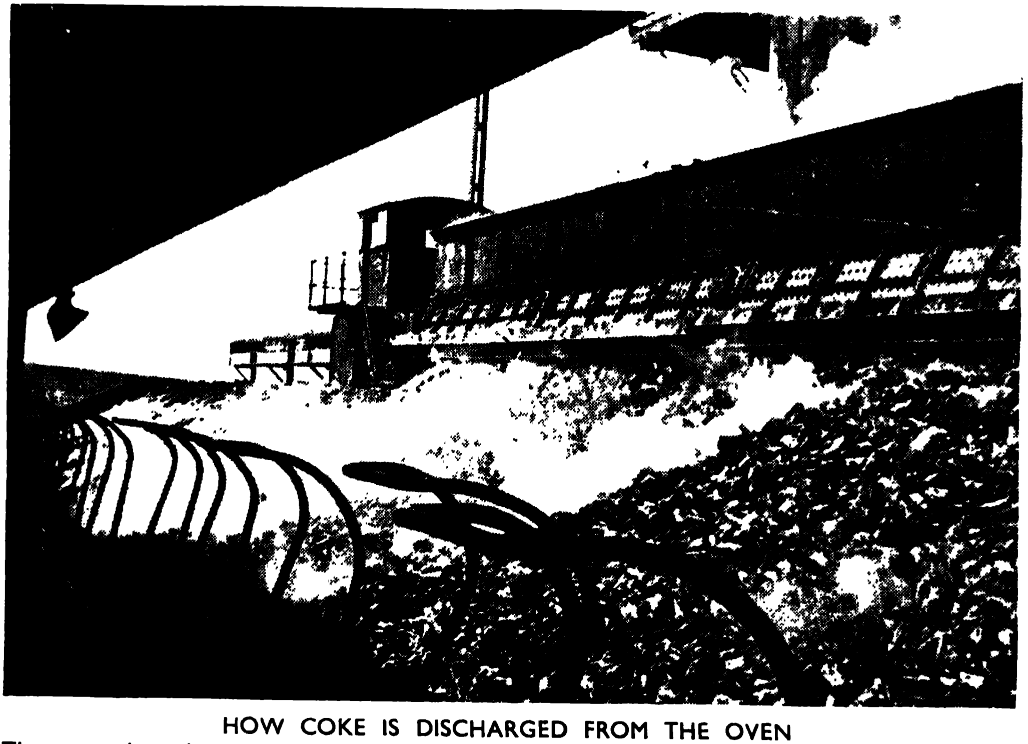


GAS PRODUCER IN SECTION

Fig. 9. This drawing of the gas producer beneath a set of horizontal retorts shows how coke is charged into the vessel lined with refractory material and is supported on bars beneath which air is passed. Oxygen from the air combines with carbon from the coke to form carbon monoxide. This gas then passes to the combustion chamber.

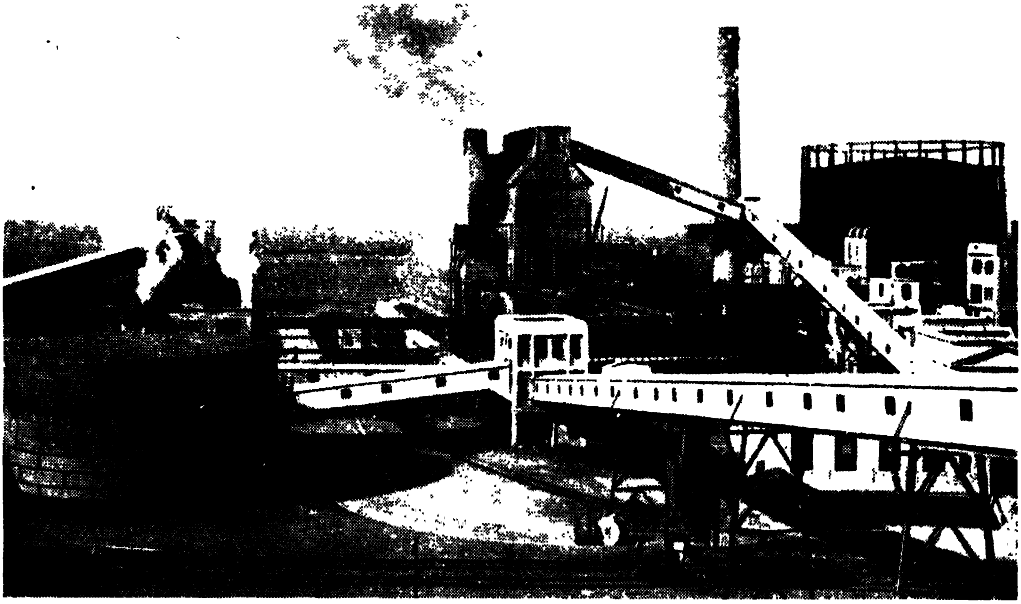
centigrade. The retorts are usually shaped like the letter D lying on its back, and are about 20 ft. long with openings at each end. The ends are, of course, both closed during the period of gas making. As a general rule the retorts are charged automatically by a machine called a larry, which pushes in about 18 cwt. of coal at one end (Fig. 5), and simultaneously pushes out what has become coke at the other end. Fig. 6 shows a stoker attending to a horizontal retort during carbonization.

The retorts are built into what is known as a setting, which consists of a series of vertical walls which support the retorts along their length and are so constructed as to give free passage of the heating gases around the retorts. In the setting the retorts are built up into sets of anything from three to ten retorts (Fig. 7). The coal takes about twelve hours to become carbonized at the end of



HOW COKE IS DISCHARGED FROM THE OVEN

The oven coke is discharged by means of a gigantic electrically driven ram, mounted on rails, which, when carbonization is done, can be halted in front of any desired oven to carry out its purpose.



A FEAT OF ENGINEERING—THE COKE OVEN PLANT

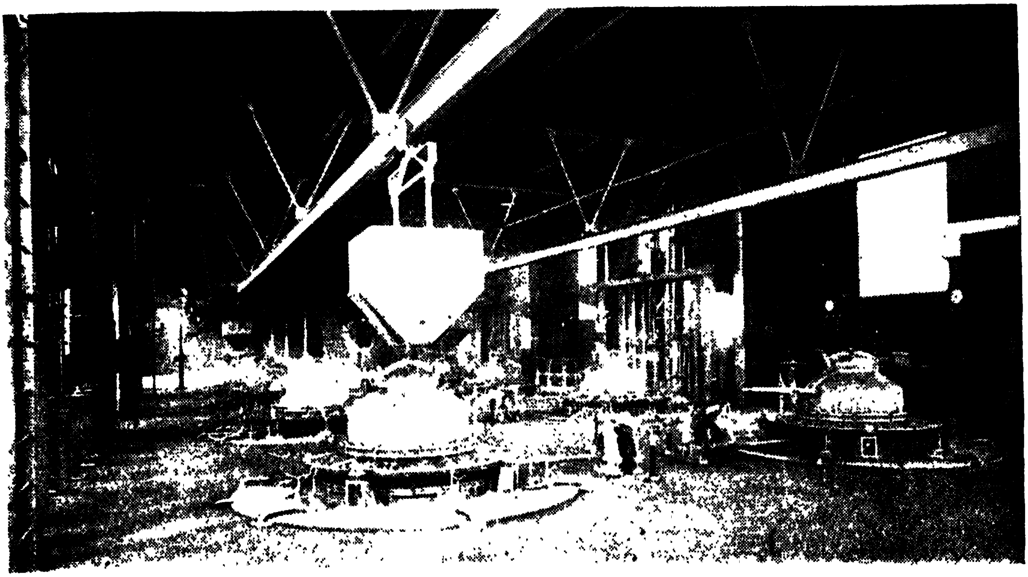
Fig. 10. This general view of a coke oven plant shows how coal is elevated to the top of the ovens and the complex system by which coke is removed for grading and taken to the pier for shipment.

which time refuelling takes place and the hot coke which is being replaced by coal is guided into a trough and discharged from the retort as shown in Fig. 8.

Let us now consider how the producer gas, which heats the retorts, is made. Air passes under the bars of a producer (Fig. 9) situated below the setting and containing coke, and oxygen from the air combines with carbon from the coke to form a combustible gas, namely carbon monoxide. This gas is in turn mixed with air and burns in a combustion chamber, the hot products of combustion passing around the retorts to heat the coal and in this way to drive off the coal gas and tarry vapours.

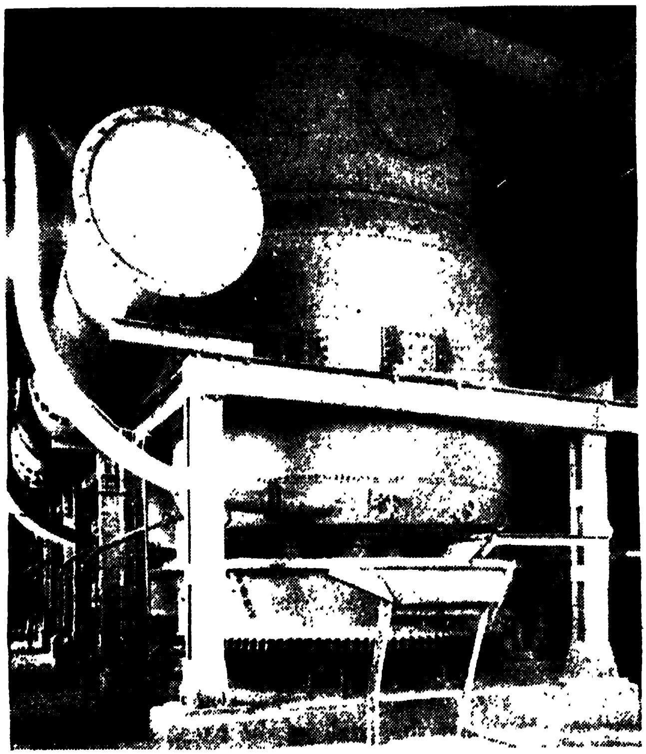
Another method of making gas is to carbonize it in retorts which are mounted vertically instead of horizontally, the operation being continuous. Continuous carbonization in vertical retorts has the advantage of producing more gas on a given ground space, and is generally a quieter and cleaner process. A diagrammatic section of this type of retort is shown at the near end of the battery of vertical retorts (Fig. 4).

Coal suitably crushed is elevated by a conveyor to the storage hopper from which it is fed into the sealed hoppers at the top of each retort. As the coal passes down the retorts it is gradually carbonized and the resultant coke is continuously withdrawn into sealed coke boxes, from which it is discharged, cold, at suitable intervals. The retorts are supported in a combustion chamber in which gas from the producer is burnt with a regulated quantity of air. The waste flue gases are led off through a flue to a waste heat boiler where their remaining heat is used to generate steam before passing out through the chimney at the far end. The gas and vapour made from the coal in the retorts ascend via



INTERIOR OF A WATER GAS PLANT

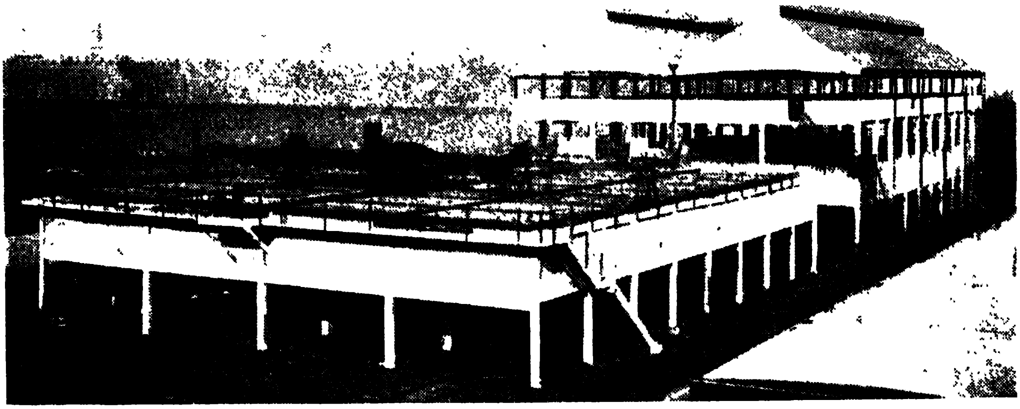
Figs. 11 and 12. Water gas is a mixture of combustible gases, carbon monoxide and hydrogen, made by passing steam over hot coke and is so called because it is partly made from water. Steam can be admitted to a retort at the bottom and the water gas thus made passes up through the retort and mixes with the coal gas produced by carbonization. Here is the upper part of a water gas plant and the tops of a battery of eight generators are to be seen. The one in the foreground is about to be charged with coke from the travelling hopper. Fig. 12 (below) shows the lower part of these water gas generators. An auxiliary water gas plant forms a part of the general layout of a gas works which is given in Fig. 4. This gas also passes to the primary condenser.



offtakes to the foul gas main.

When steam is passed over hot coke, it combines with carbon to make two combustible gases, carbon monoxide and hydrogen. This mixture is known as water gas because it is actually made, in part, from water. Steam can be admitted to the retort at the bottom, and the water gas thus made passes up through the retort and mixes with the coal gas made as a result of the carbonizing process. The process can, of course, be made intermittent. In Fig. 4 an auxiliary water gas plant is shown.

A third method of carbonizing coal is by means of coke ovens, which are long, rectangular boxes about 40 ft.

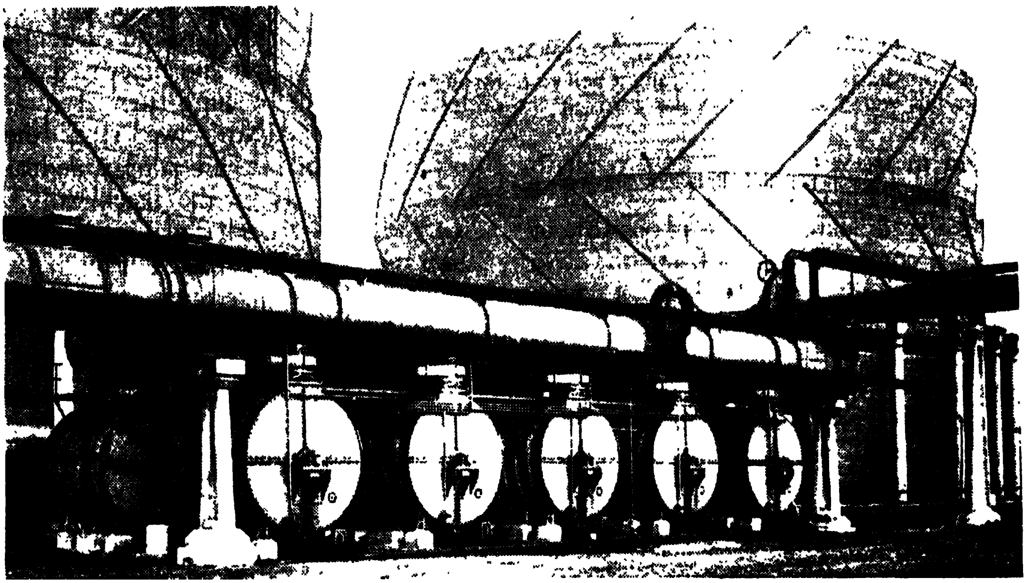


HERE, LAYERS OF IRON OXIDE ABSORB IMPURITIES

Fig. 13. In ferro-concrete oxide purifiers the gas passes through layers of iron oxide which takes out the hydrogen sulphide it contains. A further stage is to remove naphthalene from the gas

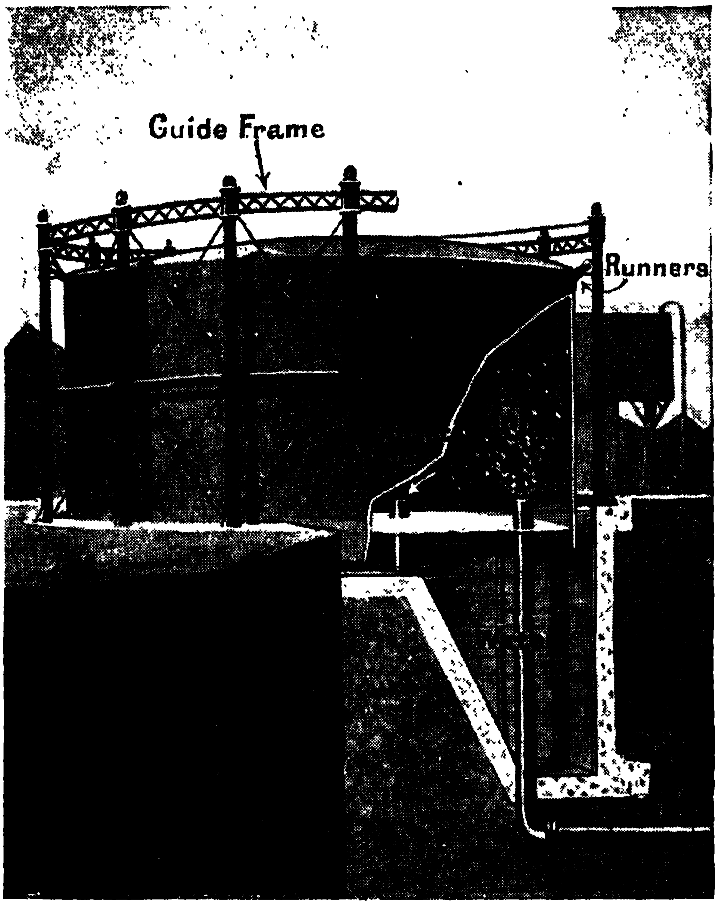
long, 10 ft. to 15 ft. high, and about 18 in. wide. Each oven is heated by a system of flues along its sides. A battery of coke ovens consists of anything up to 100 ovens in a block, and, as will be seen from the view of a coke oven plant (Fig. 10), magnificent feats of modern engineering are achieved in providing its very elaborate equipment.

Briefly the operation of this type of plant is that crushed coal is fed through lids into the ovens. The amount of coal charged depends, of course, on the size of each oven, and may be as much as 15 tons per oven. The period of carbonization is about nineteen hours. An interesting feature is the method of expelling the coke from the ovens by means of a gigantic electrically driven ram, mounted on rails which can be



REMOVING NAPHTHALENE FROM THE GAS

Fig. 14. Rotary washers remove naphthalene. This is done by means of oil in the washers, tar and naphthalene being removed by a pipe, the gas passing to a benzol recovery plant afterwards



A GUIDE-FRAMED GASHOLDER

Fig. 15. In the cylindrical water tank a bell rises through the pressure of gas, its weight forcing the gas through the outlet to the mains.

descence. The gases then formed pass out to a carburettor—a vessel containing checker bricks, which are firebricks arranged rather like a honeycomb. In passing through, the gases heat these bricks and eventually proceed to a superheater which similarly contains checker bricks. After passing up the superheater the gases emerge through a stack valve to the flue. Here, there is usually a waste-heat boiler which generates steam from the heat that would otherwise not be turned to use.

What we have done so far is to make the coke in the generator incandescent and to heat up the carburettor and superheater to a high temperature. Now we stop the blower, shut off the air supply and at the same time shut the stack valve. Then the actual water gas making begins. Steam is admitted and passes through the hot gas to form water gas, and oil is injected to enrich it. The two processes of heating and gas making proceed alternately and continuously. They are also completely automatic.

Hydrogen sulphide is removed from the gas by means of purifiers, which are large boxes containing oxide of iron and nowadays constructed of ferro-concrete (Fig. 13). The oxide is in layers on grids through which the gas passes; the impurity being absorbed by the oxide.

halted in front of any desired oven to carry out its purpose.

As already explained, it is possible to make a combustible gas from hot coke and steam known as water gas, or, more correctly, as carburetted water gas. In most gas works there is a separate water gas plant which is used as an auxiliary to the coal gas plant. In briefest outline this method of making gas is as follows: From the charging hopper, shown on the left of the water gas plant in Fig. 4, coke is fed into a generator which is also seen as one of a battery of eight in Figs. 11 and 12. A blower forces air through the hot coke and raises it to incan-

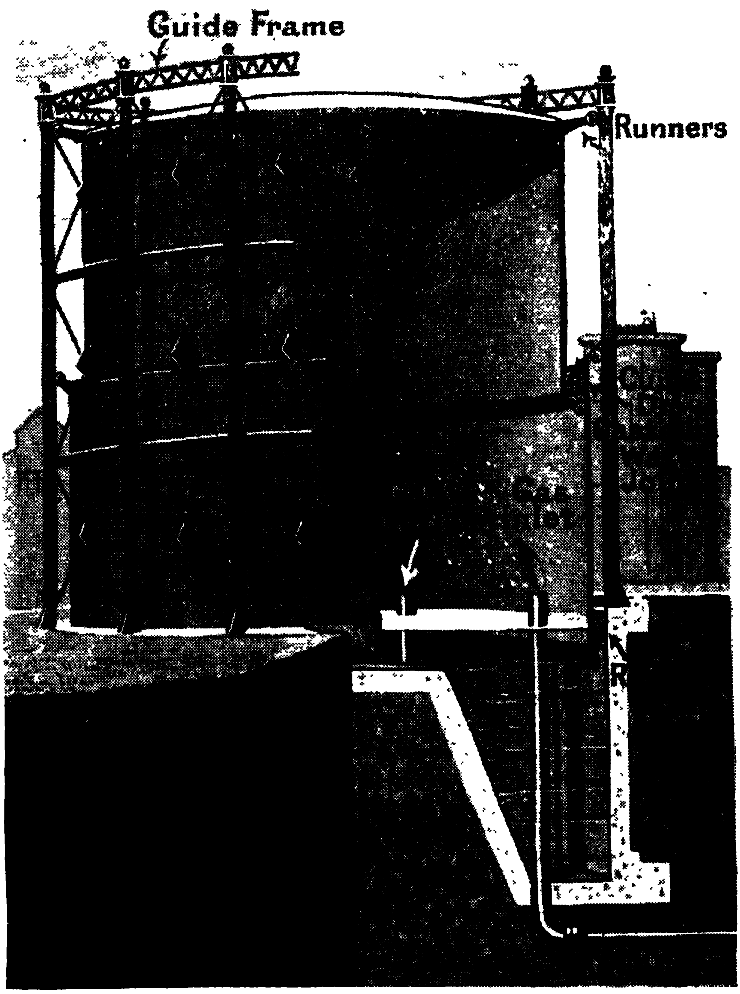
A diagram is incorporated in Fig. 4.

Naphthalene is removed from the gas not only because it serves no useful purpose and is liable to cause blockages in pipes in cold weather, but also because it is very useful as a by-product. It is removed by passing the gas through drums as shown in Fig. 14. These contain brushes rotating in oil.

Gas is not used at the same rate at all times—either of the day, the week or the month. We like our hot Sunday meals in winter, but we may go out for picnics in summer and not require gas. Similarly, in most homes, Monday is often a day for having cold food.

All manner of factors affect the demand for gas, so it is most convenient to be able to make it at a steady rate and then store the surplus for times of greater demand. This is where the gasholder serves such a useful purpose both to the maker and the user of gas. And by the way, *never* speak to a gas man about a gasometer—there's no such thing. The proper name is gasholder, since it stores the gas, not measures it.

There are four types of gasholders (Figs. 15 to 19). They are the guide-framed, the spiral-guided, the pressure, and the waterless. Fig. 15 shows the simplest form of guide-framed holder. A cylindrical tank holds water, and in this a bell is free to rise and fall, its movement being controlled by posts and runners. Gas enters and forces the bell to rise. Under the pressure created by the weight of the bell the gas is forced through the outlet to the mains in the streets and thence to the consumers. Larger holders have two or three concentric bells which telescope as shown in

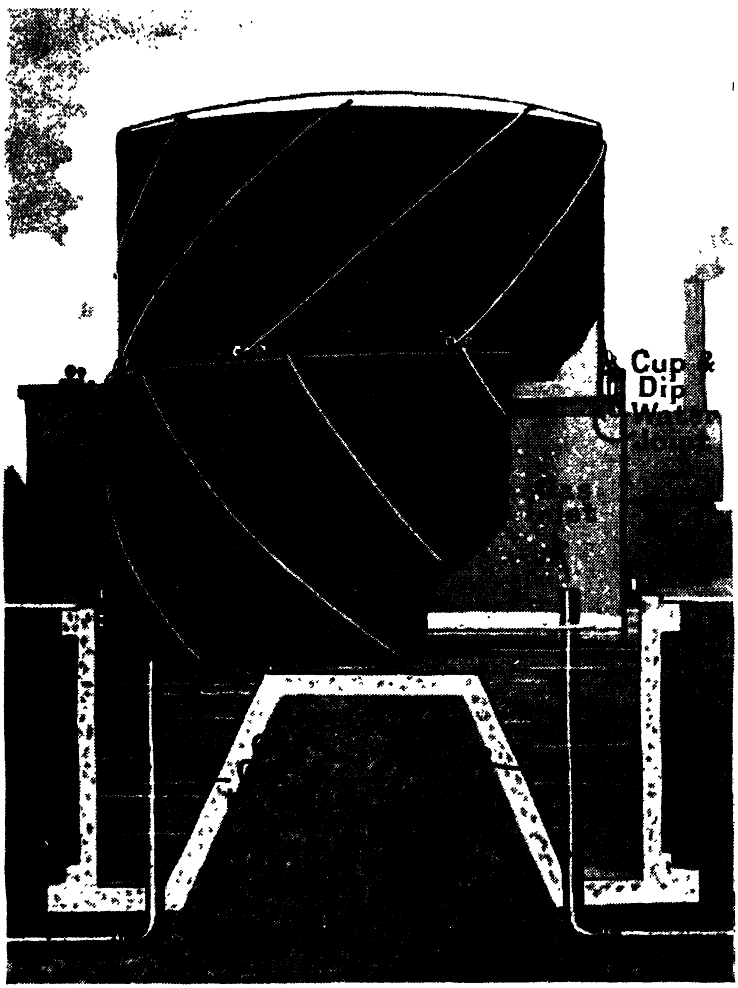


GUIDE-FRAMED GASHOLDER WITH TWO BELLS

Fig. 16. A larger holder of the type shown in Fig. 15, this, instead of a single bell, has two or three bells though the principle is the same as in the simpler form. The concentric bells telescope as shown above.

Fig. 16. The spiral holder (Fig. 17) is on the same principle except that the guide posts are dispensed with and, instead, guide rails are fitted to the sides of each bell and engage with guide rollers, so that they telescope into one another like a huge screw being turned. Fig. 18 illustrates the waterless gas-holder, which is a cylinder in which a circular piston is free to rise and fall, its edges being kept gastight by a tar seal. The space above the piston is open to the atmosphere through vents. Access to the holder is by means of a lift and then down through the top where there is a ladder down to the piston. This ladder folds up as the piston rises (page 30). Pressure holders are merely tanks in which gas is stored under pressure. They are sometimes cylindrical and sometimes spherical as shown in Fig. 19.

Gas undertakings' areas of supply are frequently like huge grids; gas being made at more than one gas works which are inter-connected. The object of gas distribution is to ensure a constant and adequate supply to every consumer. Large mains leave the works and smaller mains branch from these into every street. From each street main, service pipes are taken into individual premises. Pressure is kept uniform and constant by means of automatic regulators in underground chambers in the street at certain suitable points. Sometimes high-pressure mains are laid to remote parts of a district which has developed beyond the capacity of the normal mains to fill its needs. This high-pressure gas is then reduced in pressure locally. This is usually done automatically according to the local



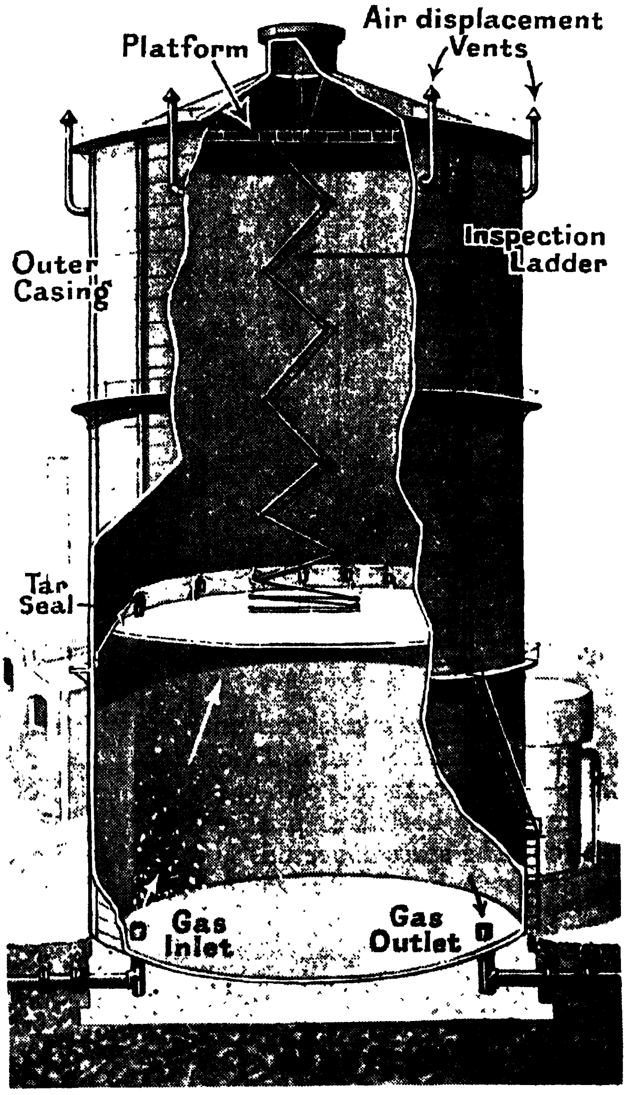
A SPIRAL GAS HOLDER

Fig. 17. The spiral holder is on the same principle as those shown in Figs. 15 and 16 except that the guide posts are dispensed with and rails fitted into the side of each bell engage with guide rollers so that they telescope into one another like a screw being turned.

demand for gas. In some instances local gasholders are erected so as to provide an adequate supply of gas where it is required at periods of great demand. Such holders may be many miles away from the gas works, from which they are filled during relatively quiet periods so that the gas is ready where and when it is wanted. Fig. 20 shows the pumping room in a gas works where the necessary pressure is generated.

We shall not have time to look at all the by-products and see how they are made into commodities of national importance, but before we leave the gas works we ought just to glance at the coke plant. The coke from the various methods of carbonization is conveyed to the coke grading plant (Fig. 21), where it is cut and sorted into standard sizes (Fig. 22) required for various industrial and domestic sizes.

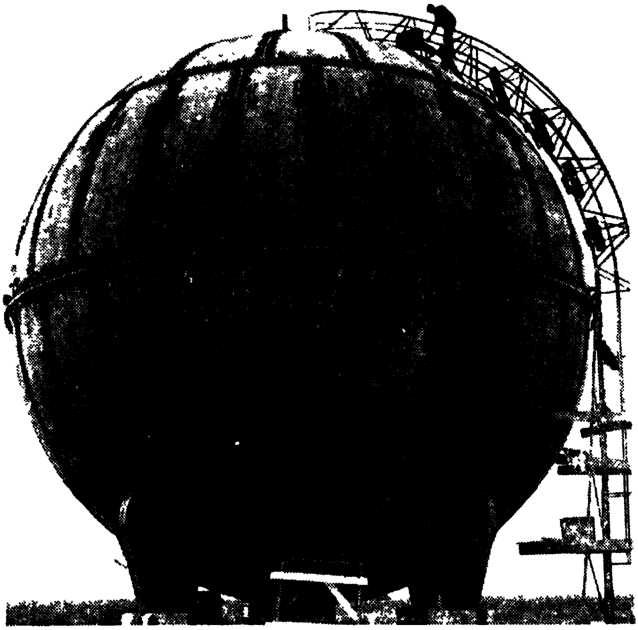
There are two main types of meters for measuring gas used by domestic consumers—the wet meter, which derives its name from the fact that it is partly filled with water or oil, and the dry meter, which contains no fluid. Although wet gas meters are still used to a great extent in many other countries, their use in Britain has been almost entirely superseded by the dry meter (Figs. 23, 24 and 25).



A WATERLESS GASHOLDER

Fig. 18. The waterless gasholder is a cylinder in which a circular piston is free to rise and fall. Its edges are kept gas-tight by a tar seal. The ladder folds up as the piston rises.

The dry gas meter belies its outer appearance. From casual observation it is just a metal box with two pipes attached to it, and a row of mysterious dials behind a piece of glass. Actually, it is an extremely accurately made and scientifically designed measuring instrument. Moreover, the accuracy of all gas meters supplied to the public must be checked and certified by inspectors of gas meters, appointed by the local authorities, and working to regulations issued by the Board of Trade. The law requires that meters must be accurate within extremely narrow limits.



A SPHERICAL PRESSURE GASHOLDER

Fig. 19. The spherical or cylindrical type of holder is made of steel plates and contains gas at high pressure.

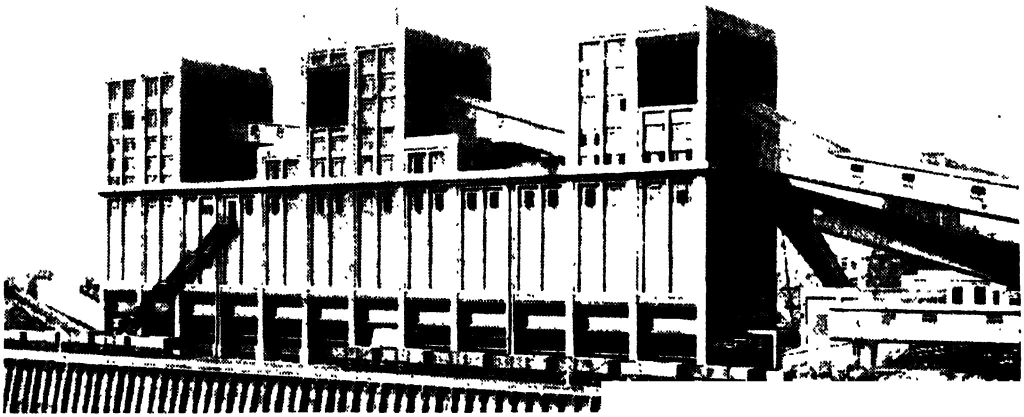
two sliding valves and the recording mechanism as seen in the plan view (Fig. 24). The space below the attic is divided by a vertical partition into two equal compartments T and t (Fig. 23). To each side of this partition is attached a flexible measuring chamber or bellows, S, s. These bellows consist of a circular metal disc attached by leather diaphragms (shown more clearly in Fig. 25). The diaphragms are made from the finest selected skins of East India (Persian) sheep. Since the leather can inflate and contract like a concertina, the chambers can move outwards when filled with gas and move inwards when the gas is expelled.

A dry gas meter consists essentially of a heavily tinned steel casing divided into three compartments as shown in Fig. 23. There is one horizontal partition near the top. The space above this is called the attic or valve chamber and contains

The motive force for operating a gas meter is the pressure of the gas above that of the atmosphere. Entering at the inlet I the gas finds one of the valves V in such a position that port P is open, allowing free passage to the in-

PUMPING ROOM AT A GASWORKS

Fig. 20. The gas is pumped out from the gasholders to the system of large and small mains.

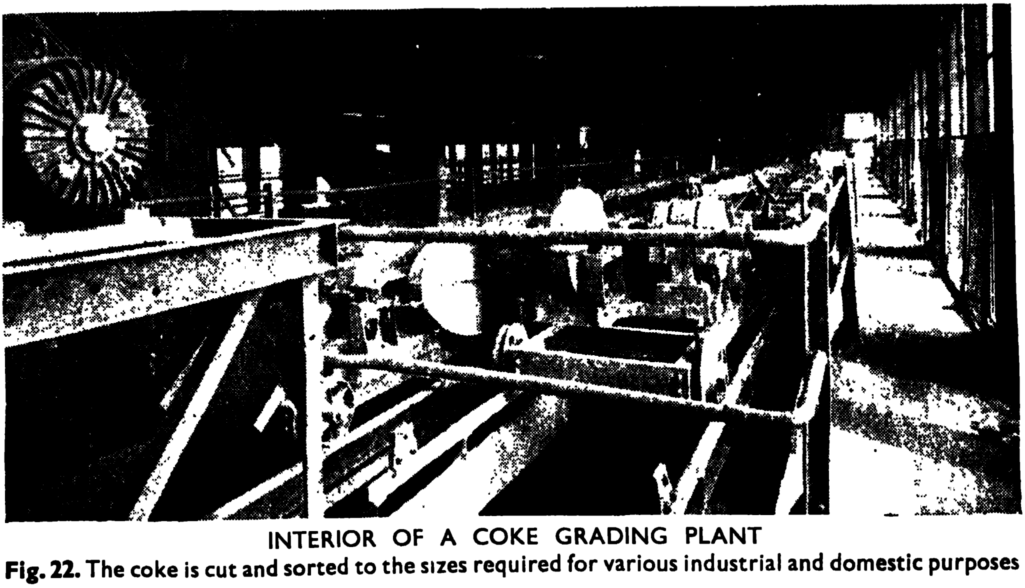


MODERN COKE GRADING PLANT

Fig. 21. Coke is automatically sorted into graded sizes and conveyed to ships or loaded into trucks.

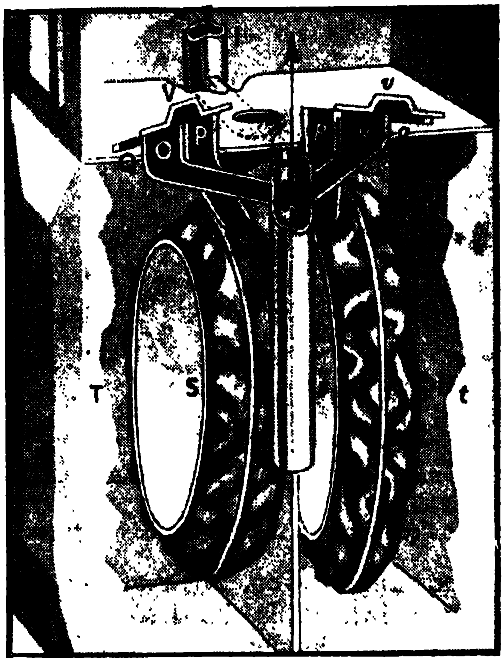
terior of bellows S. The bellows therefore inflate and, in so doing, expel an equivalent volume of gas from the outer compartment T under the valve, via ports Q and O to the outlet of the meter. This movement of the bellows has, by means of gearing, caused the valves to slide across their respective ports until Q is open and gas can enter T and expel the gas in the bellows S from which it is expelled via P and O to the outlet. The opposite is happening in the other bellows. The movement of the two bellows is timed so that one works a little in advance of the other to obviate any check in the flow of gas at the change over of the ports. The travel and size of the bellows is accurately fixed and determines the exact volume of gas received and expelled. They work very much like a twin cylinder steam engine.

The movement of the valves is geared to the recording mechanism which rotates the hands of the dials which



INTERIOR OF A COKE GRADING PLANT

Fig. 22. The coke is cut and sorted to the sizes required for various industrial and domestic purposes

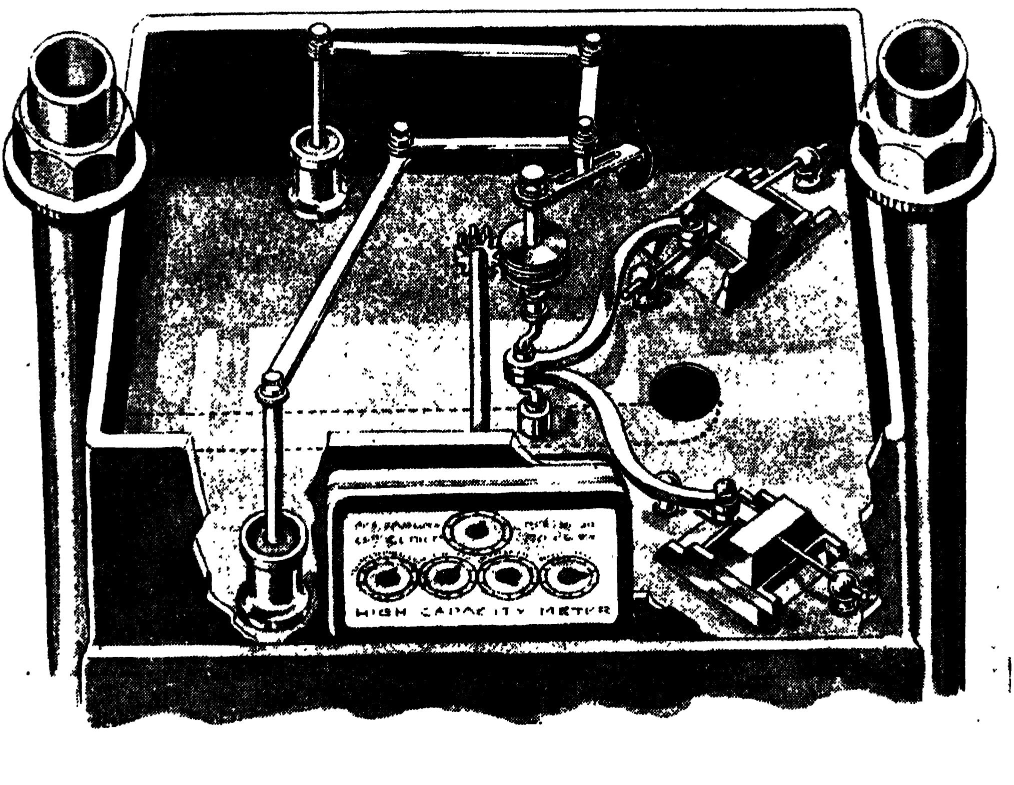


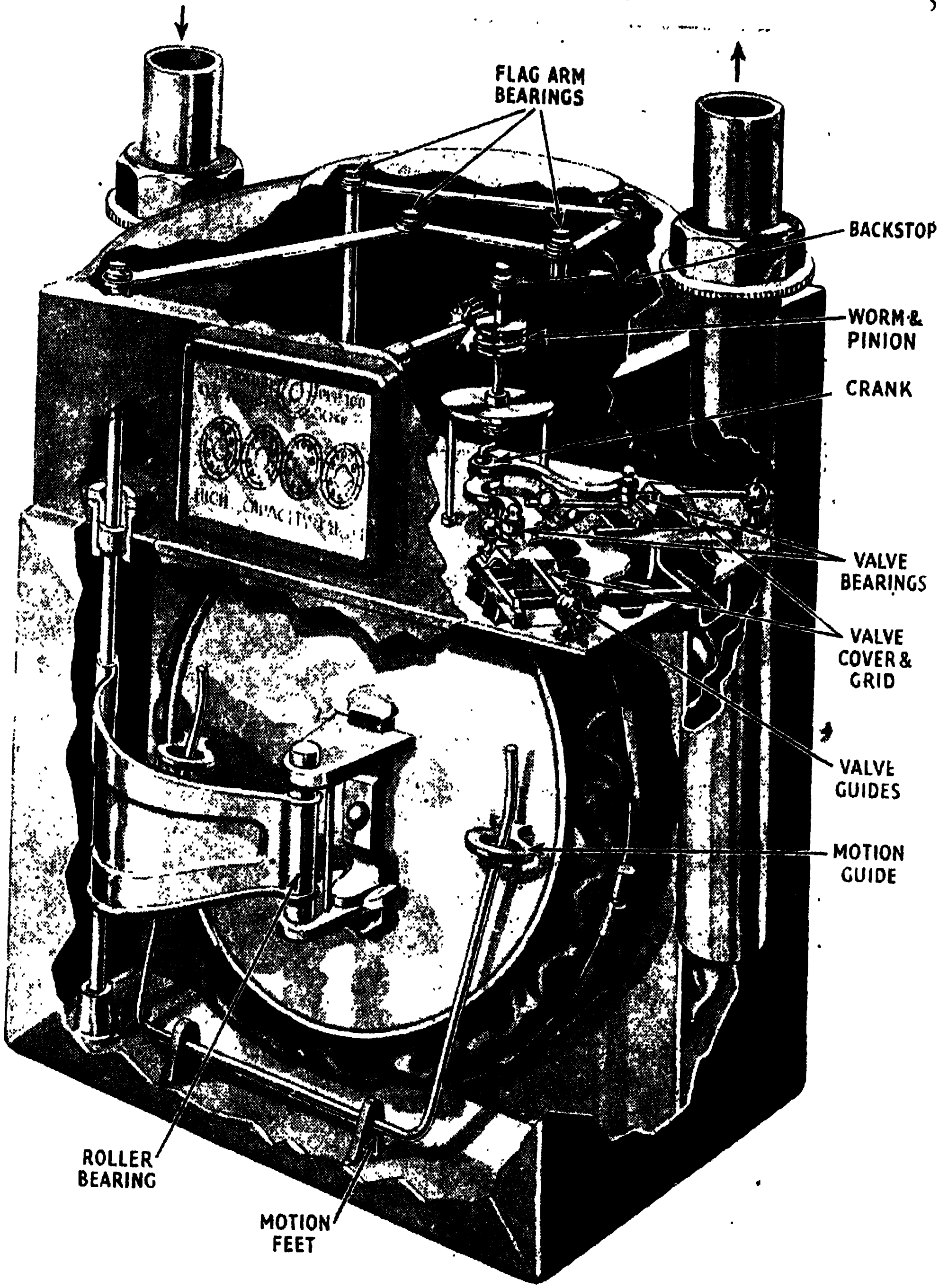
CROSS SECTION OF DRY GAS METER

Figs. 23 and 24. The diagram looking end on above shows the division into measuring chamber and valve chamber. The latter is seen below.

indicate the quantity of gas consumed.

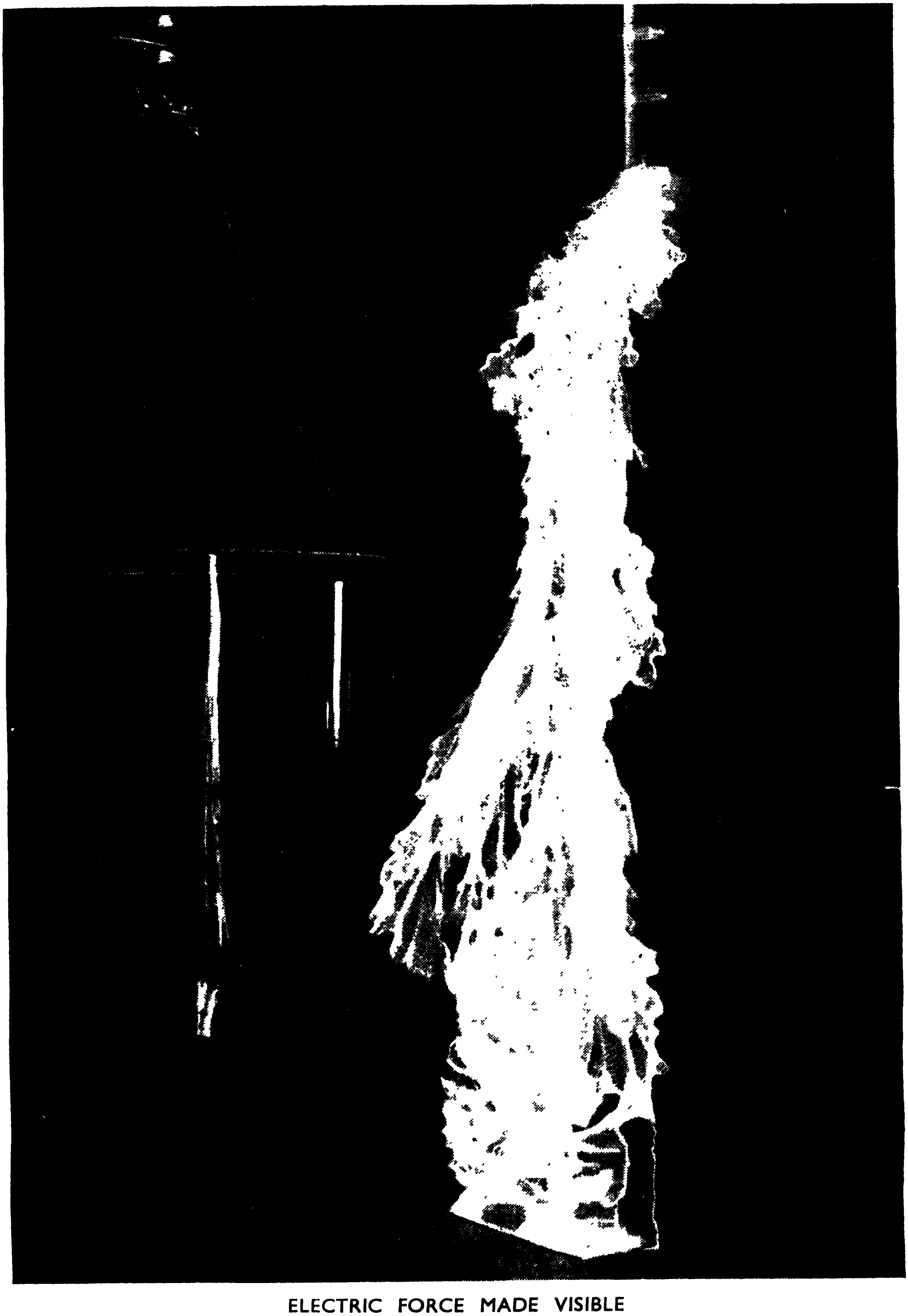
Slot meters (more correctly known as automatic prepayment meters) are the same as ordinary meters, but have an additional attachment which consists of an admission valve geared to a coin mechanism. When a coin is inserted and the handle turned, the coin acts as a connexion which rotates the gears back through a certain distance and opens the valve. The meter will thus have to operate through a pre-determined number of revolutions before the valve closes and another coin has to be inserted. The number of revolutions is arrived at by the volume of gas sold for the coin inserted. If a number of coins are inserted together, the gears will be turned back pro-rata to the number and gas to that value will have to be consumed before the valve will close. Some modern prepayment gas meters have dual coin attachments which permit of both pennies and shillings being used at will.





INTRICATE MECHANISM BY WHICH YOUR GAS IS MEASURED

Fig. 25. This cut-away view of a dry gas meter gives the names of some of the moving parts. Note the bellows metal discs attached by leather diaphragms, in principle of working very much like a twin-cylinder steam engine. The movement of the valves is geared to the recording mechanism Fig. 24 (on opposite page) gives the plan of a dry gas meter, looking from the top, with the cove removed. The valves slide over the parts and rotate the arms—known as a tangential gear—which in turn, rotate the hands of the dials which indicate the quantity of gas consumed.



ELECTRIC FORCE MADE VISIBLE

A 1,000,000-volt flash is produced at the National Physical Laboratories. The physicist thus creates his own lightning and is able to make visible the mysterious force which is called electricity.

HOW WE HARNESS ELECTRICITY

The nature of Electricity. The modern power station. The turbo-generator. The control of current. The grid system. The transformer. Stepping down the voltage. The three-wire system of distribution. Variations in the day's load. Electricity at work in the home.

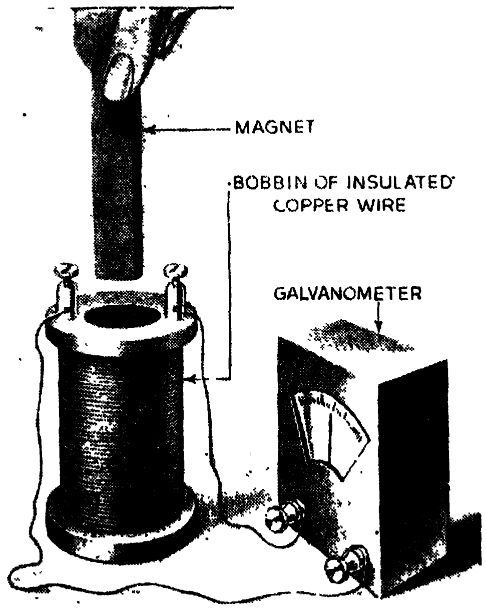
ELECTRICITY is now admitted to govern our lives to a quite inescapable extent, even had we the wish to escape it. Yet only in fairly recent times have we succeeded in harnessing electricity to our wishes. Less than a hundred years ago its practical applications were limited to telegraphy, the telephone, and the occasional lighting of public places, piers, promenades, and a few important streets. Today in millions of homes electricity provides light and heat and saves hours of needless work, while in industry it has become indispensable to us all.

What then is this mysterious force? We know it now as something that can never be created, but merely made manifest—made manifest, for example, by friction, by chemistry, by the influence of magnetism, and so on. Scientists are still busily trying to solve the problem of the infinitely small with which the whole nature of electricity is bound up. It is believed that electricity is the manifestation of the movement of electrons, minute particles of energy that are part of the structure of all matter. Always fresh paths for research are being thrown open, and it can safely be said that many more remarkable developments in the sphere of electricity have yet to astonish us by their power and usefulness.

It is a fallacy to think that electricity can be kept in stock like gas or water. Accumulators do not really store current; they reproduce electricity by chemical action in response to a reversed chemical action previously set up. Perhaps electricity's most tremendous asset is the ease and rapidity with which it can be made to function at a distance, and thanks to this fact the simpler forms of electric telegraphy were among the first consciously utilized services that electricity was called upon to bestow. No other force can respond unerringly and with the speed of light to the mere action of a switch miles away.

FARADAY'S DISCOVERY

Electricity as we popularly know it, distributed throughout the country for domestic, public service and industrial purposes, depends upon the intensely developed application of comparatively simple discoveries. Early in the last century, for example, Michael Faraday knew that if an electric current was sent along a wire near a bar of suitable metal, such as soft iron, a state of magnetism would be set up. He considered how the phenomenon could usefully be reversed, as it were, and discovered that if an electric conductor were suitably moved near a magnet a current would flow (Fig. 1). The intricately wound electrical generators in power stations today depend for their output on this simple principle (Fig. 4), complicated



A BASIC DISCOVERY

Fig. 1. When the bar magnet is pushed into the bobbin a momentary current flows in the wire and is then indicated by a 'kick' of the galvanometer needle. When the magnet is withdrawn another momentary current flows, but in the opposite direction and will be indicated on the galvanometer. This is a vital principle.

coils of wire being rapidly rotated in powerful magnetic fields, and a succession of myriad small amounts of current suitably amassed, so that powerful currents are obtained.

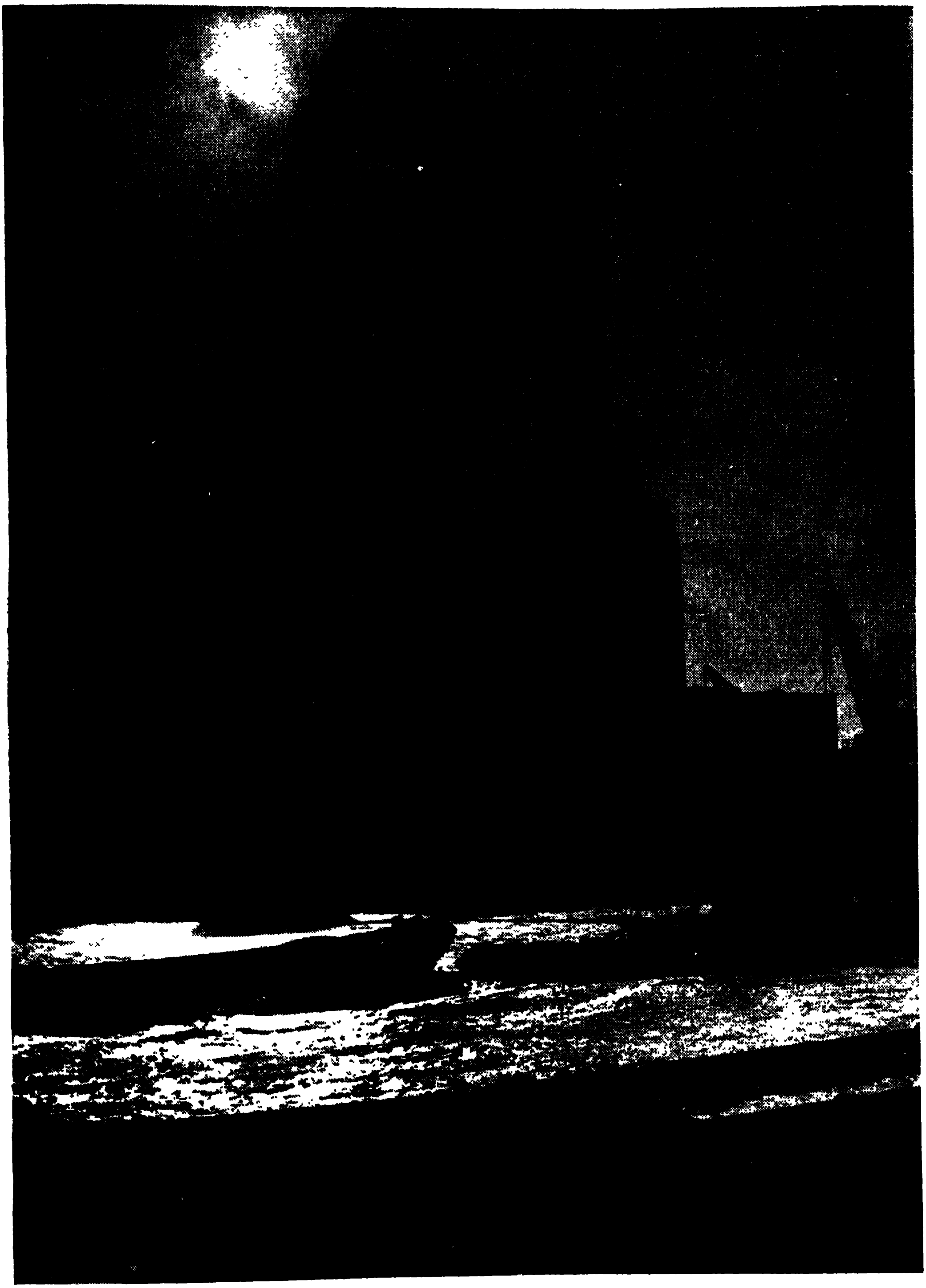
Currents may be so collected that they are direct, that is flowing continuously in one direction, or alternating, that is being reversed with great rapidity—fifty reversals a second, for example. Alternating current acts, for many purposes, very similarly to direct current, and has the advantage that it can be readily transformed into currents of varying pressures—or voltages. This is important since it is more practicable to transmit electricity over long distances at a high voltage, transforming it at the far end to the lower voltage at which eventually it will be used.

How and why did our present vast power stations come into existence? The immense organization of modern electric supply had small beginnings, the lighting of comparatively small areas being almost all that was attempted. As designers and manufacturers improved the electric motor, and began to find all sorts of ways in which electricity could be used industrially and in the home, the demand grew rapidly, and the hundreds of small electric light works were not nearly equal to meeting it. Some wise engineers realized that it would be far better to generate in a few very large stations than in many of medium size, but years passed before their ideas were accepted.

A remarkable advance came when the steam turbine was applied to the generation of electricity. Until then reciprocating steam engines, or gas engines, had been the only means of driving the generators. Turbines enormously increased output, with economy of space. Within a few years the true power station appeared, generating sets became larger, and electricity permeated the whole structure of nations. From our modern central stations comes the current that runs electric trains, trolley buses and tramways, turns the massive rolling mills of iron and steel works, drives the machines of factories and operates the electrical services which are now installed in countless homes.

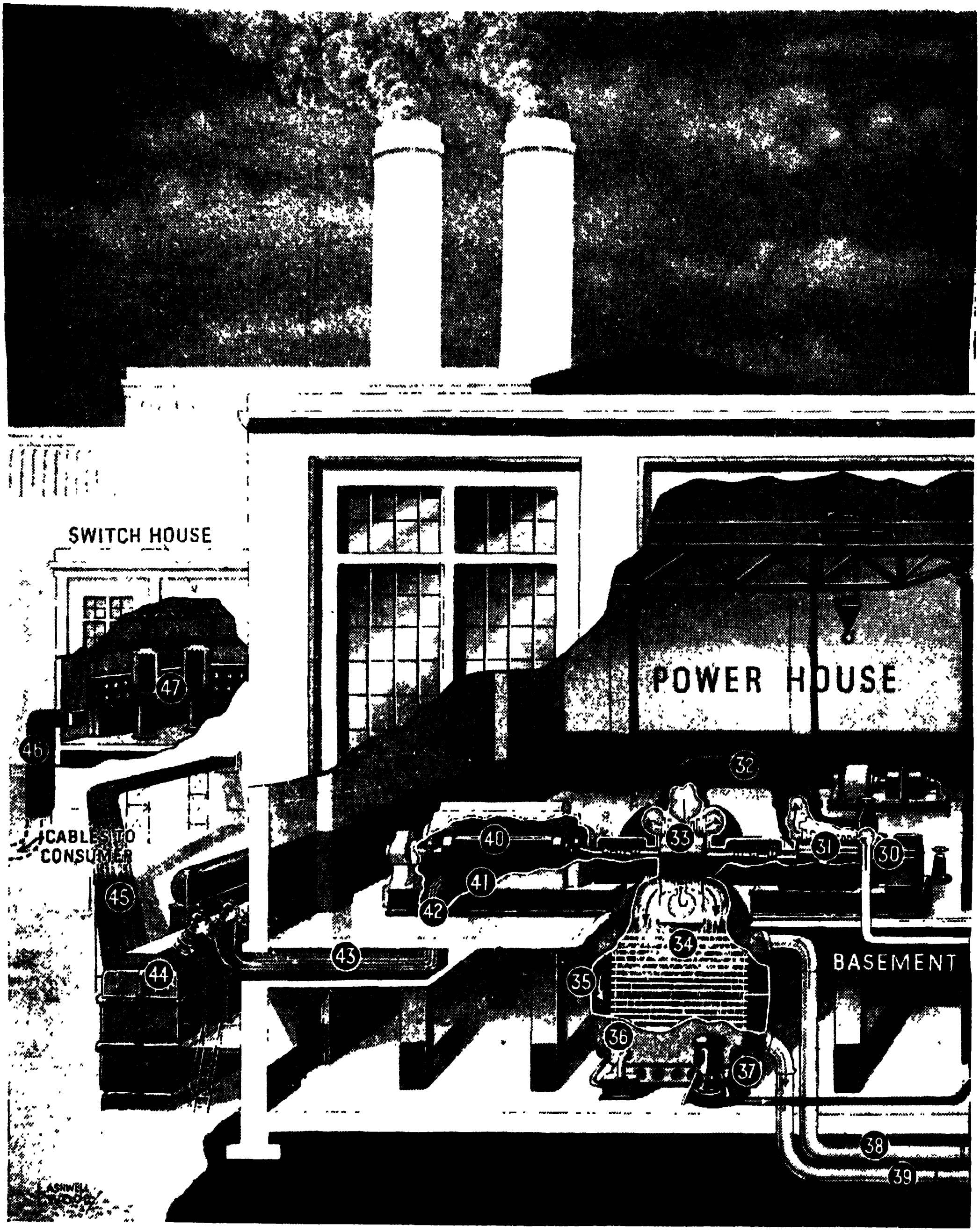
ELECTRICITY'S MYRIAD USES

Innumerable processes of manufacture depend on electricity, and thousands of delicate instruments—recording, testing, measuring, indicating, controlling, and so on, depend upon it for their action. In addition to this, the many operations that are carried on by means of batteries—the running of electric vehicles and trucks, telephone exchanges, motor car lighting, starting and ignition, for example—all depend upon the main supply by which batteries must be recharged



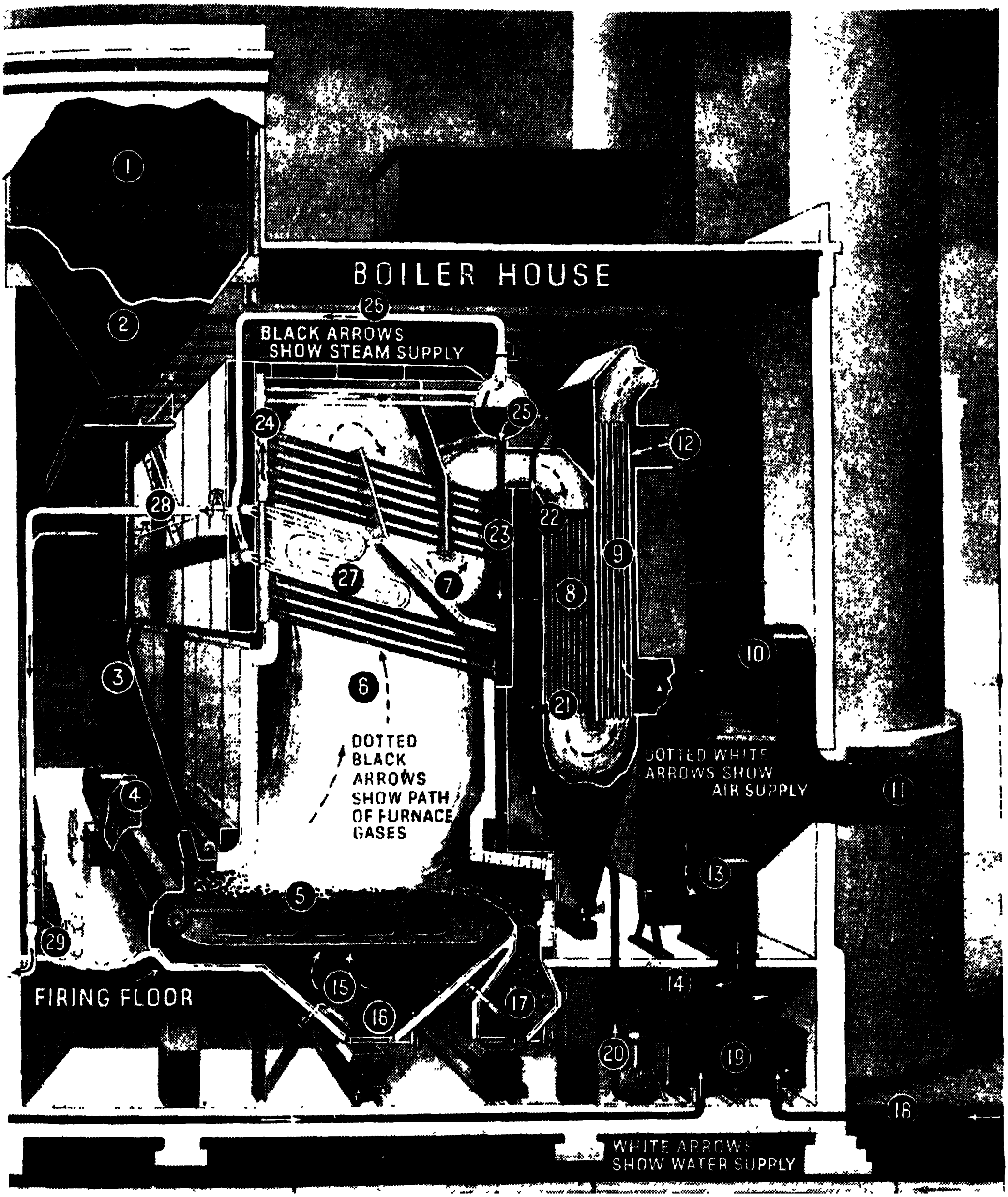
MAJESTIC AND STRONG—A GREAT POWER STATION

This is an impressive view across the Thames of Battersea Power Station. One of the best additions to London's modern architecture, it remained impregnable against the most severe of bombing attacks. The interior arrangement of such a power station is shown on the following pages



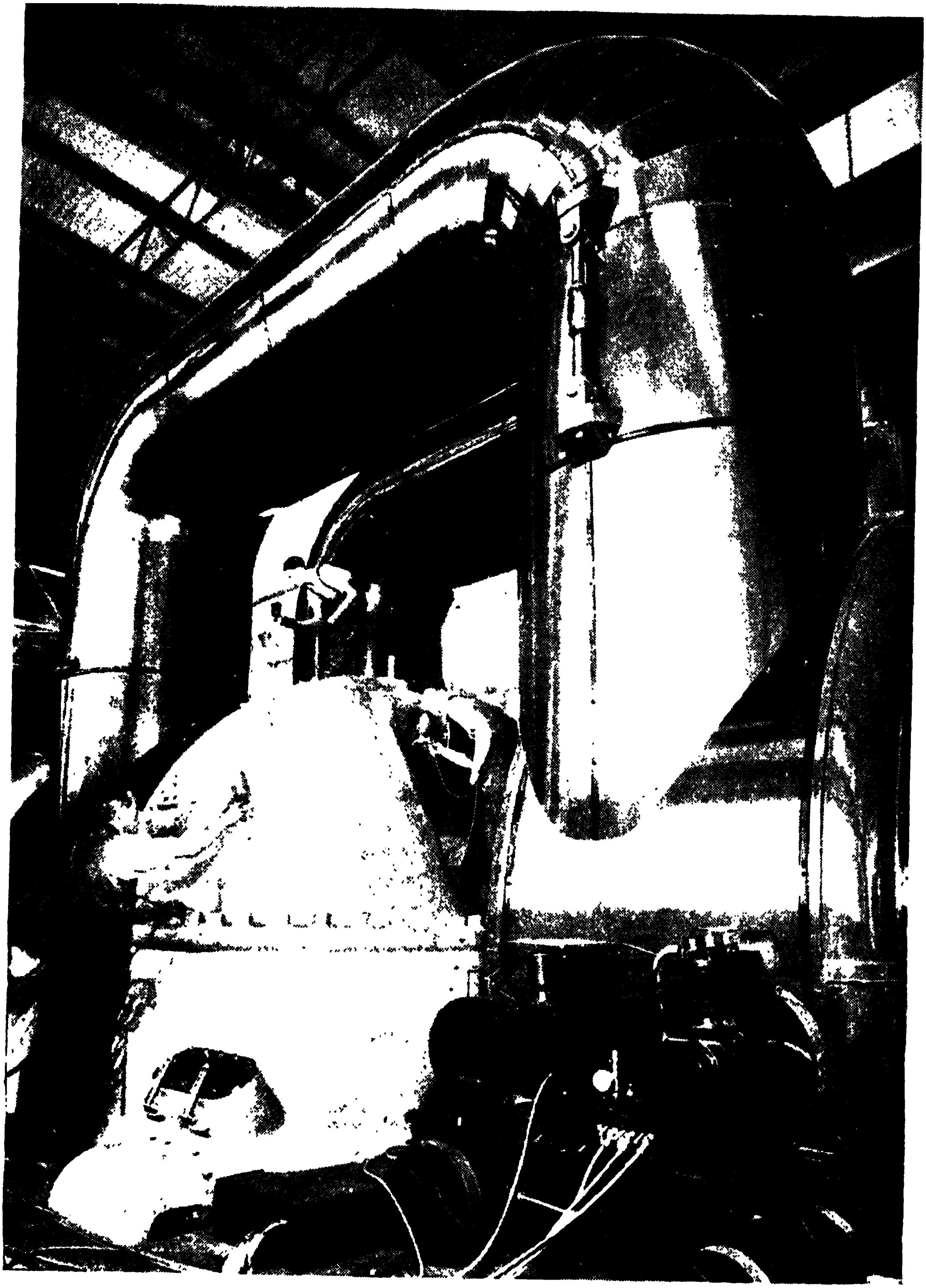
A MAMMOTH POWER PLANT

Fig. 2. First, steam is generated at 600 lb. per sq. in. This drives the 92,000-h.p. turbine at 150,000 revs. The generator develops 70,000 kilowatts or 70,000,000 electrical watts, at 11,000 volts pressure. This is stepped up to 66,000 volts for distribution to the mains. Key to working parts, in rotation, is as follows: FURNACE SYSTEM: 1, Coal conveyor; 2, coal bunker; 3, coal chute to furnace; 4, electric motor driving stoker; 5, moving chair gate stoker; 6 and 7, hot gases and air passing through furnace; 8, feed water heater; 9, incoming air pre-heater; 10, suction discharge fan; 11, furnace gases passing to chimney. AIR SYSTEM: 12, cold air inlet; 13, induction fan; 14, heated air duct to furnace; 15, heated air entering furnace; 16, fine ash hopper; 17, clinker hopper. STEAM SYSTEM: 18, Cold water supply; 19, feed water tank; 20, feed water pump; 21, feed water



FOR GENERATING ELECTRICITY

heating tubes; 22, heated feed water supply to boiler; 23, boiler water tubes; 24, steam rising; 25, steam and water drum; 26, steam pipe to superheater; 27, superheater tubes; 28, high-pressure steam pipe to turbine; 29, turbine regulating valves. TURBINE SYSTEM: 30, High-pressure steam inlet; 31, blades and rotor of high-pressure turbine; 32, exhaust steam pipe to low-pressure turbine; 33, blades and rotor of low-pressure turbine; 34, exhaust steam passing over condenser tubes; 35, cold water through condenser; 36, vacuum pump; 37, pump returning distilled water to feed tank and boiler; 38 and 39, cooling water pipes. GENERATING SYSTEM: 40, 70,000 kilowatt generator; 41, magnetic fields; 42, 11,000-volt cables; 43, cable tunnel; 44, step-up transformers to 66,000 volts; 45, cables to switchhouse; 46, 66,000-volt switches; 47, distribution cables.



FROM THIS MACHINE ELECTRICITY STARTS ITS JOURNEY

Fig. 3. A large turbo-alternator at a modern power station. The generator is attached to the shaft of the turbine, the complete set being called a turbo-alternator or turbo-generator.

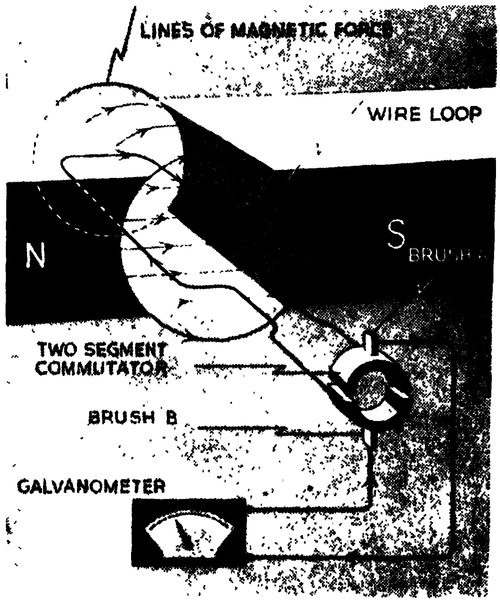
after use. Lastly, electricity comes into our homes as the universal servant that never grows tired and wants no time off.

What happens when we touch the switch that sets this servant at work? How does this mysterious invisible agent reach us? We must remember, in the first place, that in Britain electricity has to be generated mainly by heat engines. Except in a very few mountainous and isolated districts where water power and storage are available, the production of steam by the burning of fuel is the first step.

HOW POWER IS GENERATED

First comes the coal mine and the trains of coal trucks on their way to the power station sidings; or perhaps the coal is water-borne to the wharves. There it is emptied—sometimes the trucks are upset bodily by a tippler—the coal being conveyed to its vast storage space by mechanical means. Most big stations have a laboratory in which samples of coal are constantly tested for calorific—heat-producing—value. The boiler house may be referred to as a kind of cathedral of steam—no longer a scene of noise and dirt and grimy stokers shovelling coal into glowing furnaces (Fig. 2). The furnaces are there, but they are fed by mechanical stokers, or by jets of pulverized coal—as fine and soft as fuller's earth—that burn fiercely like gas. Several hundred tons of coal a day are consumed, and the disposal of ash and refuse from the fires becomes a serious matter. Special machinery has always to be installed to attend to this; and arrangements have often to be made to prevent fine grit and injurious gases escaping from the chimneys and being carried round about by the wind.

The steam, at a pressure that varies according to the type of plant, and may be anything from 250 to 600 lb. per sq. in.—higher pressures are the subject

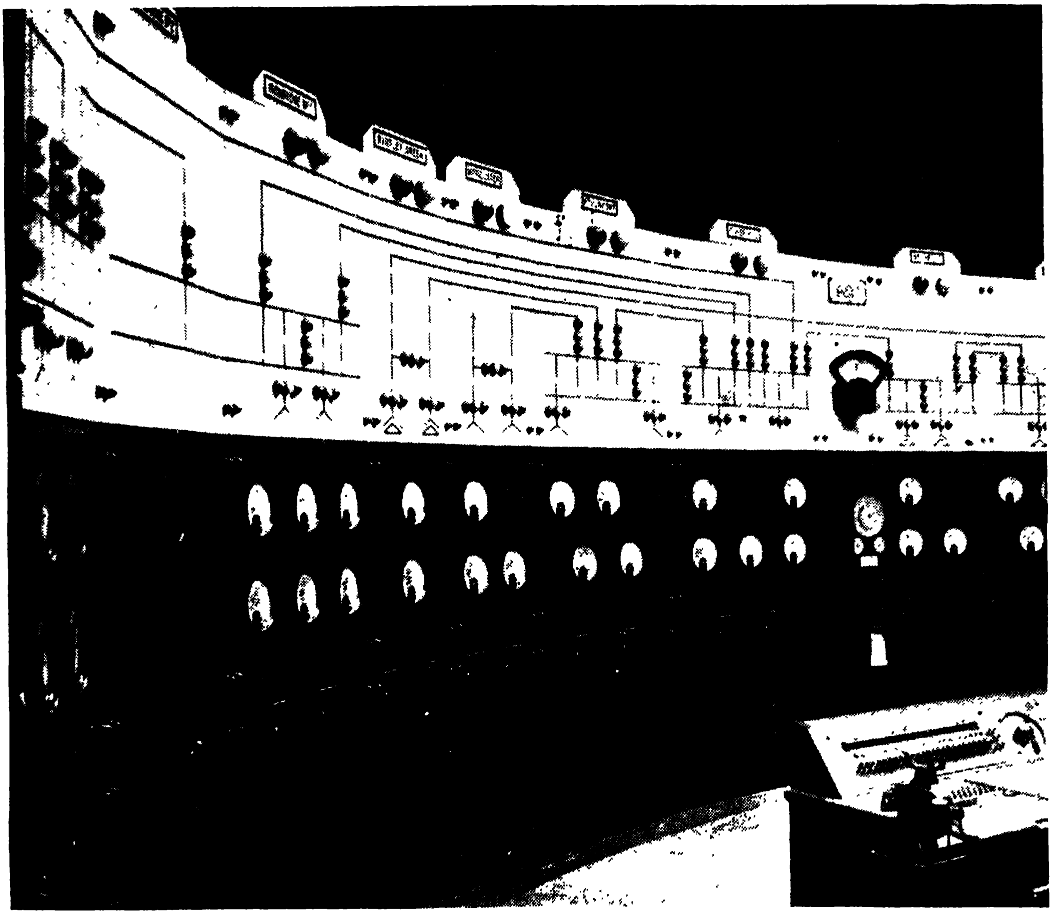


PRINCIPLE OF THE DYNAMO

Fig. 4. The revolution of the wire loop between the poles of the magnet causes rapidly reversing momentary currents in the wire which can be collected by strips of insulated metal from the commutator. These strips are known as "brushes." Powerful currents are obtained by the application of this principle.

of experiment, but at least one station in this country has a boiler working at 1,100 lb. per sq. in.—passes to the turbines in the engine room adjoining. All their running parts—the thousands of revolving blades which the steam whirls round at 3,000 revolutions a minute—are cased in, and there is no visible moving machinery. In the electric light works of earlier days the dynamos used to be driven by belts from the engine flywheels; now the generator, massive descendant of the dynamo, is attached to the shaft of the turbine, the complete set being termed a turbo-alternator or turbo-generator (Fig. 3); and it is from this machine, or from several of them, connected electrically, that the electricity starts on its journey.

Having done its work the steam is led to the condensers, iron chambers through which cooling water flows; the

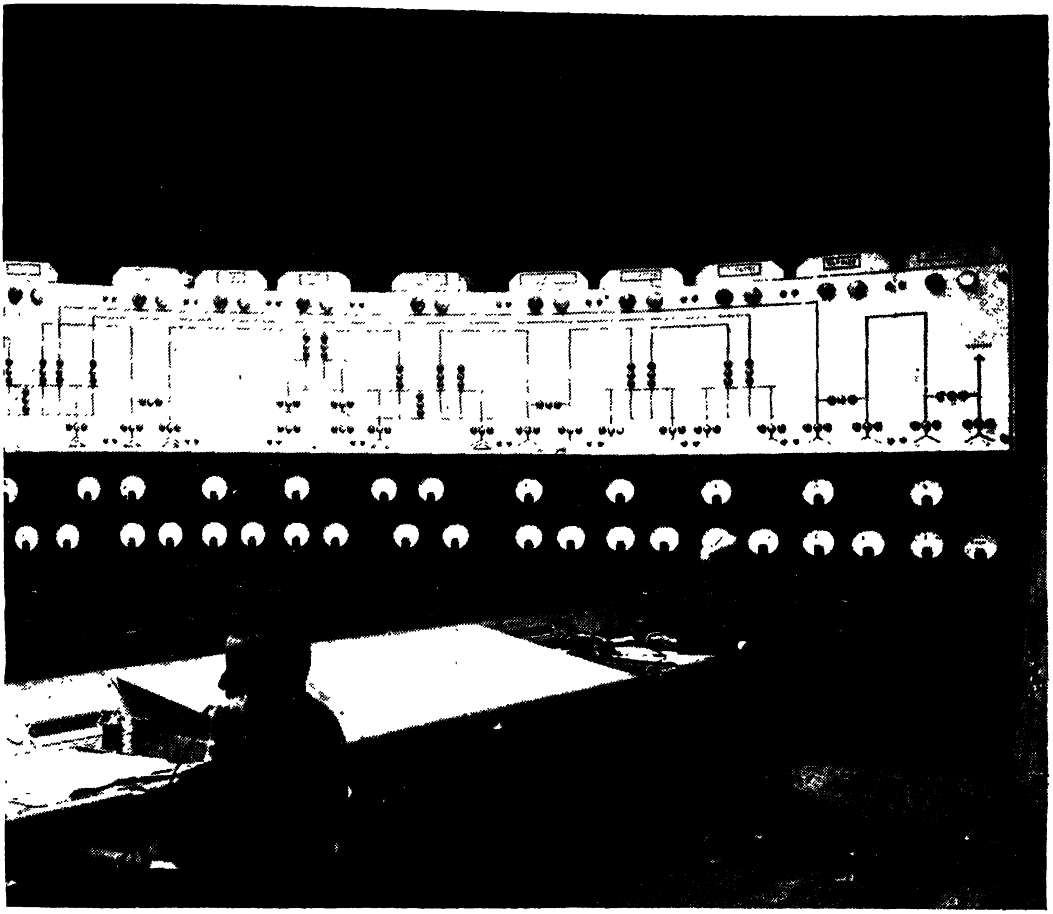


CONTROL ROOM OF A POWER STATION

Fig. 5. The whole of the central England area of the grid is controlled from this room. The names round the top of the panel refer to different power stations supplying certain towns and districts.

steam passes through them in hundreds of small pipes, returns to its original state of water, and is pumped back into the boilers hot. If the station is built on a river bank, the circulating water for the condenser is drawn from the river at the rate of several million gallons an hour, through a tunnel which may be from 5 ft. to 10 ft. in diameter, and discharged into it, after passing through the condenser, appreciably warmer. This, of course, is lost heat, but not nearly so great a loss as if the steam were exhausted into the atmosphere. When river water is not available, cooling ponds and cooling towers serve the same purpose, the circulating water being pumped up and allowed to fall in thin streams, being chilled in its slow downward course.

All stations have their switchboard galleries or control rooms. Switches, large or small, may be termed the electrical equivalent of the taps that turn on or off a water supply; they turn on or interrupt the flow of current. The heavy switchgear of a power station is housed in a separate building and carefully protected; for when anything goes wrong with high-voltage supply an almost explosive force is liberated and things happen very quickly. The con-



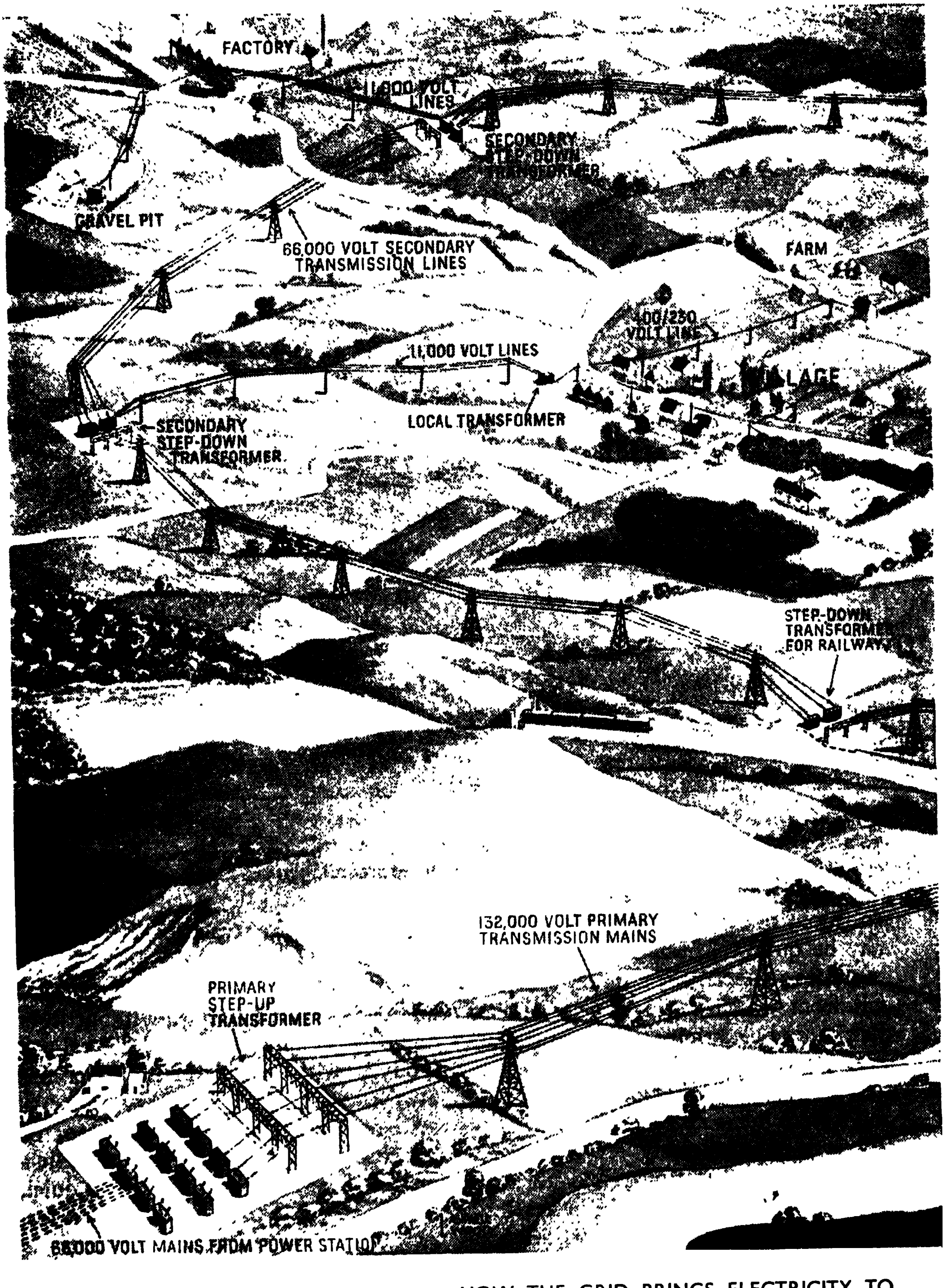
SERVING A LARGE DISTRICT
From such a room, on instructions or information received by telephone, the supply of each section can be increased, diminished, cut off, or modified according to the requirements of the load.

trol room of an entire electrical system may be quite separate from the station or stations concerned; a quiet, spacious hall from which begins the process of distributing electricity to different areas. Fig. 5 shows such a control room.

Briefly, the idea behind the grid system was to generate electricity in quantity at a comparatively few large and highly efficient stations, and to turn many of the existing smaller ones into distributing centres. Tall transmission towers or pylons bear the overhead cables from town to town, and today the British National Grid is one of our finest engineering systems (Fig. 6)

Before the construction of the grid, when each station supplied its own area and none other, a breakdown meant that a whole district might be without light and power until repairs had been done. Today, with many different stations always pouring their energy into the grid network, the service need not be interrupted, as a rule, for more than a matter of minutes; there are a few quick telephone calls, the operation of a few switches, and one part of the country is linked up to supply another part perhaps a hundred miles away.

Into the pool of the grid, then, our electricity has passed through from the



HOW THE GRID BRINGS ELECTRICITY TO

Fig. 6. The 66,000-volt cables from the generating station go underground to the primary step-up transformer. Here the current is increased to 132,000 volts, an economical figure over long distances. Primary step-down transformers reduce this pressure to 66,000 or 33,000 volts. It

TOWN, VILLAGE AND ISOLATED FARM
is further reduced by secondary step-down transformers to 11,000 volts for rural transmission, and local transformers reduce the pressure to 400 or 230 volts for house-to-house distribution. Small stations are distributing centres, bringing electricity from a few large sources of supply.

turbo-alternator, to mingle with the current from many others; and from the grid, eventually, comes the electricity that lights and warms our rooms, cooks, and operates vacuum cleaners, refrigerators, and many other appliances.

Before it can do this, however, it has to be brought down to a much lower pressure. It is generated, maybe, at a pressure of 3,000 volts; for transmission economically, this is increased on the main grid lines to 132,000 volts; on the secondary or branching lines it varies from 66,000 to 33,000 or 11,000 volts,

CONTROL PANEL AND SIGNAL

The switches in the control room at a power station are the electrical equivalent of the taps controlling water supply. The positions on the dials are: Stand By, Start Up, Faster, Slower, On Load, Increasing Load, Reducing Load, Shut Down. The signal stands at Increasing Load on No. I Generator. The word bus on other panels signifies the bus-bars that carry the current.

or still less. To try to use electricity for household purposes at such pressures would be as sensible as trying to fill a kettle from a fire hose, and would, of course, be extremely dangerous.

For actual use, the electrical energy has to be stepped down, or transformed, to lower voltages, at which it can safely drive machinery or operate lamps.

STEPPING-DOWN THE VOLTAGE

We may refer once more to Michael Faraday, another of whose discoveries, namely, that a current flowing in one wire can cause or induce a current to flow in another wire near it, is an important factor of electrical distribution. If we bring two wires close together, pass a steady current from a battery through one of them, and switch it off after five minutes, nothing happens during the five minutes; but, at the moment when the current was switched on, and at the moment when it was switched off, a current shot for a fraction of a second through the dead wire; the two momentary currents thus induced being in opposite directions. This is the principle of the transformer (Fig. 7). Using two coils of wire, and passing through one of them alternating current at 50 cycles (which is equivalent to switching it on and off fifty times a second) an alternating current of the same frequency will be induced in the other; and—this is the significant point—the strength of the induced current will be proportional to the number of turns in the respective coils. If one coil has 100 turns and the other 1,000, the induced current in the second one will have ten times the pressure (or voltage) of that in the first. The reverse holds good; if we make No. 2 the primary, the current in No. 1 will be one-tenth of the voltage of that in No. 2, the proportion being the same.

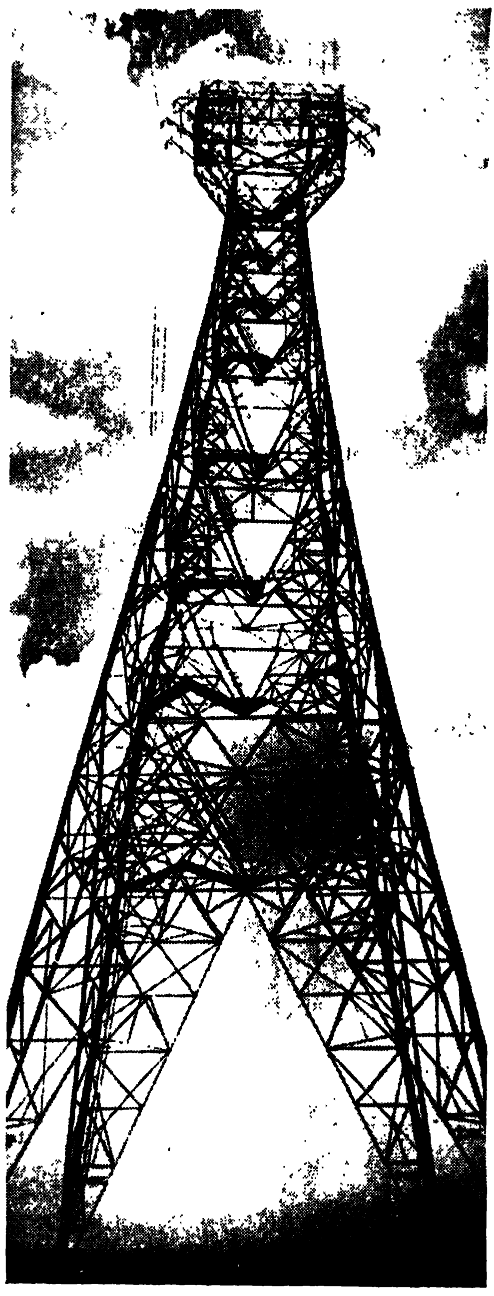
Putting the matter easily, transformers are simple appliances that can receive a

flow of electrical energy of small volume but of very high pressure, and deliver a similar flow of much greater volume but of lower pressure, and vice versa. By their use, electricity is stepped up for transmission, and stepped down for distribution to consumers; and in this process hardly any loss occurs. Some transformers weigh several tons, and have to be specially cooled, since heat is caused in the transference of energy; others—such as those used in radio sets—you can hold in one hand, but they operate on the same principle.

TRANSFORMING STATIONS

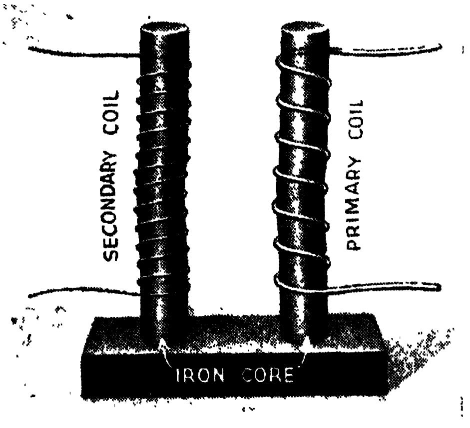
Outside many power stations today, in the open air, protected by a railed-off enclosure, you have no doubt seen a complicated-looking maze of wires and strangely shaped gear, from which cables lead up to one of the graceful latticed pylons (Fig. 8). These are the switching and transforming stations feeding the grid with electrical energy, stepping up the current from the generators to the correct voltage for transmission. The grid branches off from other transforming points, and at various distributing centres the current is brought down to a voltage at which it can be safely used to drive machinery—mills, lathes, looms—and to a still lower voltage at which it can become, as it were, domesticated. Much of its fierceness has gone when it enters our homes; still, it is not to be treated without respect, even at 250 volts.

After the high-pressure electricity reappears at lower pressure, it can be sent along larger cables, less heavily insulated, beneath streets and roads or wherever it is needed, and tapped here and there by smaller branching cables which take it to the consumers—shops, offices, houses, and other places where, after its journey, it begins to do its useful work. When very large consumers such as factories, docks, railways, and



TALL PYLON OF THE GRID

One of the grid's tallest pylons carries fourteen transmission lines across an inlet of the sea; a view taken from beneath. The height is over 360 ft.—as high as St. Paul's; it is 70 ft. square at the base; the crossing span is 1,820 ft., and the minimum clearance of the lines above high water is 150 ft. These pylons are linked up with the switching and transforming stations.



PRINCIPLE OF THE TRANSFORMER

Fig. 7. An alternating current sent through the primary coil will cause or induce another alternating current in the secondary coil of a different voltage. The strength of the induced current will be in definite proportion to the number of turns given in the respective coils.

so on, are concerned, the high tension supply is sometimes led straight into the premises and there stepped down to the pressure that happens to be required.

THREE-WIRE SYSTEM

The steady increase in the use of electricity meant, naturally, a corresponding increase in the demand for copper, which, if we omit silver, is the most suitable metal for wires and cables. Silver is a better conductor of electricity, but of course is much too expensive for the purpose. In order to enable higher voltages to be carried, and thus to improve the capacity of main supply cables without reducing their efficiency, the three-wire system of distribution was devised. With this arrangement, twice the voltage can be used; if the running voltage of the lamps supplied was 115, for instance, the pressure on the mains could be 230 volts, and therefore a saving could be secured in the amount of copper required (since the greater the voltage the lower the current). The middle wire, or neutral, between the positive and negative, connected in a special way to the source of supply, is earthed, in order that its potential above earth may not rise over a certain voltage at any point. Not much current is carried on the middle wire; its amount depends only upon the difference in the loads on the other two wires. When it became possible to manufacture reliable high-voltage lamps successfully, three-wire systems came into general use carrying 440 volts between the two outer wires, with the result of lessening still further the quantity of copper that would be required.

The term three-phase, often heard in connexion with electricity supply, has nothing to do with the three-wire system, which is simply a particular method of distribution. In the three-phase system, usual in long-distance transmission and in the industrial supply of electricity, there are three quite distinct currents, each generated in a separate winding of the alternator, each having its own separate wire or line, and each capable of being used as an ordinary current in the ordinary way.

The subdivision of the network of cables at convenient points is effected either by means of underground junction boxes or by the feeder pillars or boxes which you will often see, generally painted green, at the roadside.

Our electrical energy has now reached, literally, the doorstep of the home; for very often the cable from the street main enters the house underneath the front doorstep, and, if there happens to be a cellar, the point of entry can be seen. What happens, now that we want it to start its special work of lighting, heating, cooking, ironing, and the ever-so-many odd jobs which are so easily within its great range of power?

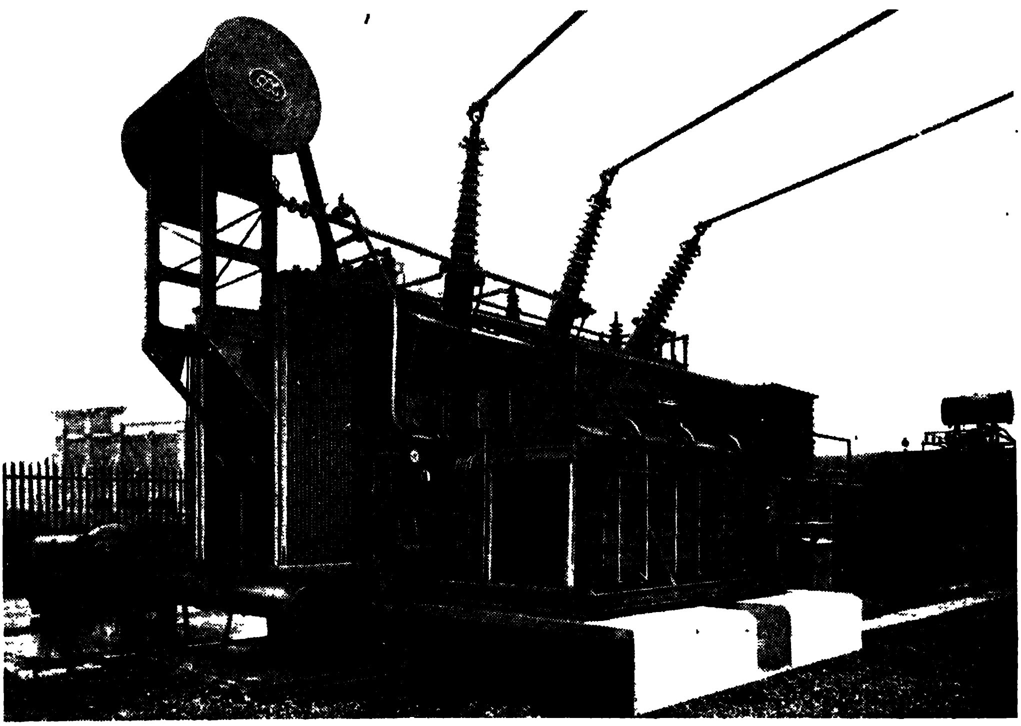
First of all the house supply can be completely switched off at the main switch, just as we can turn off the water

at the main. Electricity reaches all apparatus, lamps included, by means of two insulated wires, a lead and a return, because electricity must complete a circuit before it can do any work. When a lamp or a fire is switched off a gap is made in a circuit. The main house switch, for safety, when in its off position, causes a break or gap in both wires of the entering cable, therefore entirely severing all connexion between your house and the power station. It is known as a double-pole switch.

CIRCUIT BREAKERS

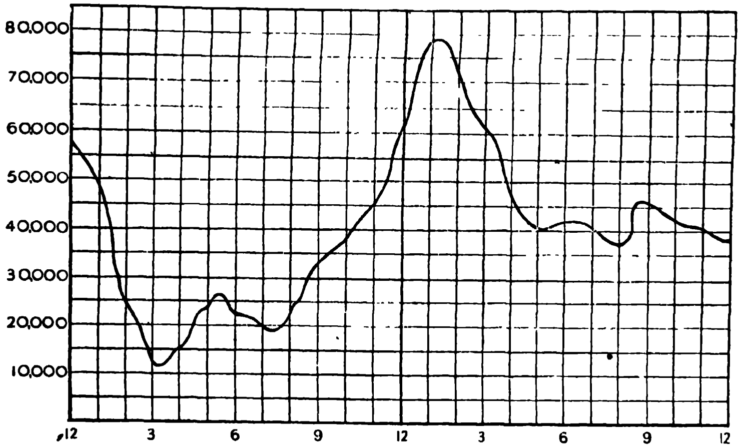
Certain types of very heavy circuit-breakers at power stations act automatically when a sudden surge of current occurs on the transmission line—possibly through lightning, or it may be some kind of mishap. Similar precautions, on a small scale, must be taken with the house current, and this is done by placing fuses in the circuit; a fuse wire, through which the electricity must pass, being a short piece of some metal or alloy of such thinness that if a rush of current occurs it will instantly overheat, melt and thus interrupt the circuit. It acts as a kind of safety valve. The two wires from the street main run via the supply undertaking's sealed fuse box to house meters and to the switches which control the lighting circuit and the heating or power circuit. From the main switch they pass to the distribution fuse board of the house. Finally, from this fuse board run the wires that serve the various floors and rooms.

The meter, or meters, tell the supply authority how much current has been used, in order that a proper charge may be made. This matter of payment has always been a source of trouble from the



A LARGE TRANSFORMER FOR THE GRID

Fig. 8. From the strangely shaped gear of the transforming station, cables lead to the pylons. Such transformers may weigh several tons and have to be specially cooled since heat is caused in the transference of energy. This transformer has a forced air blast directed on to the radiators.



HOW THE LOAD ON A POWER STATION VARIES IN 24 HOURS

Fig. 9. The amount of electricity used drops after about 11 p.m. At 7 a.m. a steady rise begins; the peak is reached at one o'clock with the midday meal. After 5 p.m. there is a steady evening load, chiefly due to lighting and heating, until bedtime. This represents an average winter day in an industrial district. Foggy or dull days increase load

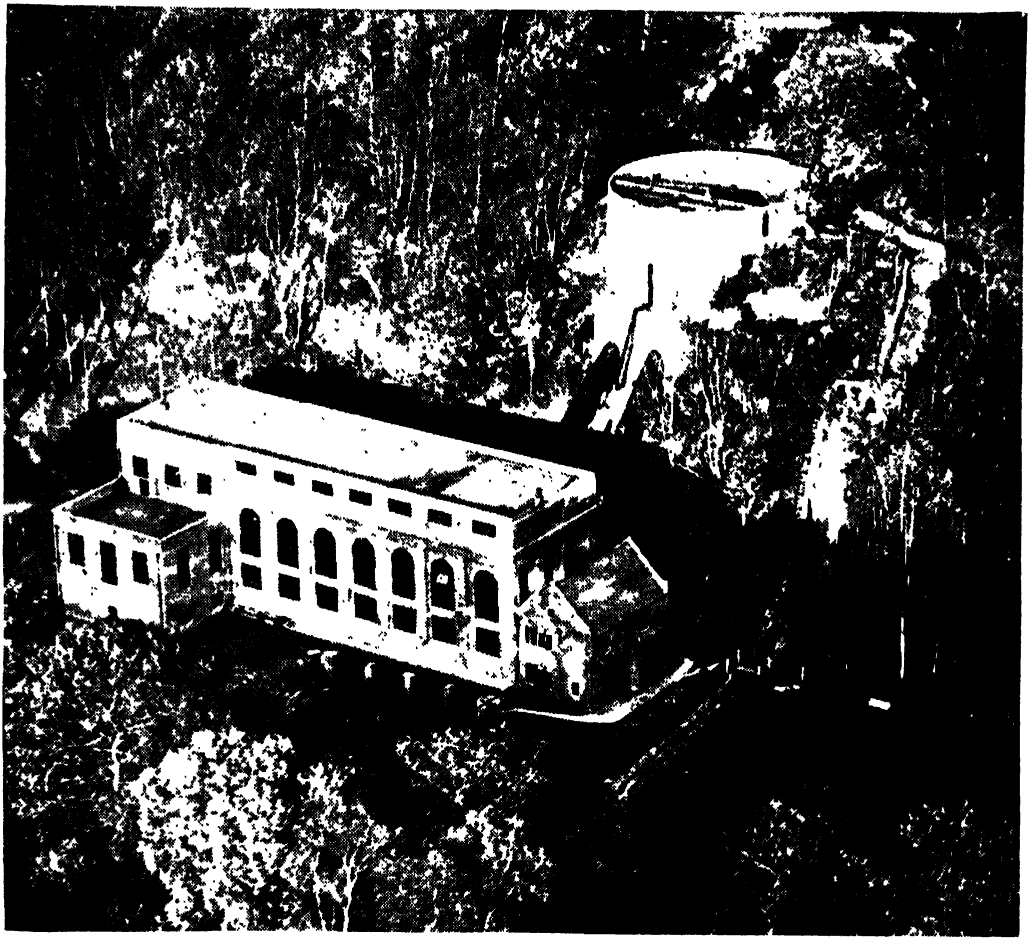
early days, because electricity, as we have noted, cannot be stored on a large scale like gas or water. Therefore, before the national grid came into operation, each power station had to possess enough spare or stand-by plant to cope with a very varying load. If you think about it for a minute you will see how remarkably the load changes as the day goes on.

Most people get up in the morning at about the same time. Thousands of electric kettles are at once switched on for an early cup of tea. Within half an hour or so the grills of thousands of electric cookers are in full swing, to say nothing of egg boilers and toasters, and in the winter on go the electric fires, with a good many lamps in the darkest period. In electrical language, this is the first peak of the day—for the moment we can leave out the industrial side and consider only the home. Then comes a drop or valley until the midday meal, for the small amount of current taken by irons, vacuum cleaners, hair dryers, and other household appliances does not create any big demand. Following the midday peak comes another interval of comparatively little consumption, and then, in winter, the evening load rises from lighting-up time and continues fairly high until bedtime (Fig. 9). A foggy day, or a very dull day, is indicated by the increased load.

Now comes the last stage: the actual way in which electricity does its work in the home. Looking round at our domestic appliances, we can see that we want light, heat and motive power.

For lighting, advantage is taken of the fact that when a current of electricity passes along a wire its temperature rises, because the wire resists its passage. Special precautions have to be taken to prevent underground cables which carry very heavy currents from becoming overheated. If the wire is small enough, it will become red-hot or white-hot, and thus emit light. In the open air such a wire would soon burn away; therefore for lighting purposes it is enclosed in a glass bulb exhausted of air and sometimes containing a little gas of a special kind (nothing to do with coal gas) which improves both the light output and the life of the lamp. Many inventors carried out hundreds of experiments before a suitable material from which to construct the hair-like filaments was discovered, and years passed before a satisfactory incandescent lamp was evolved that would stand rough usage and have sufficiently long life.

The heating of a wire, again, by an electric current is the principle of the electric fire; but as, in this instance, heat and not light is wanted, many turns of



WHERE ELECTRICITY IS GENERATED BY WATER POWER

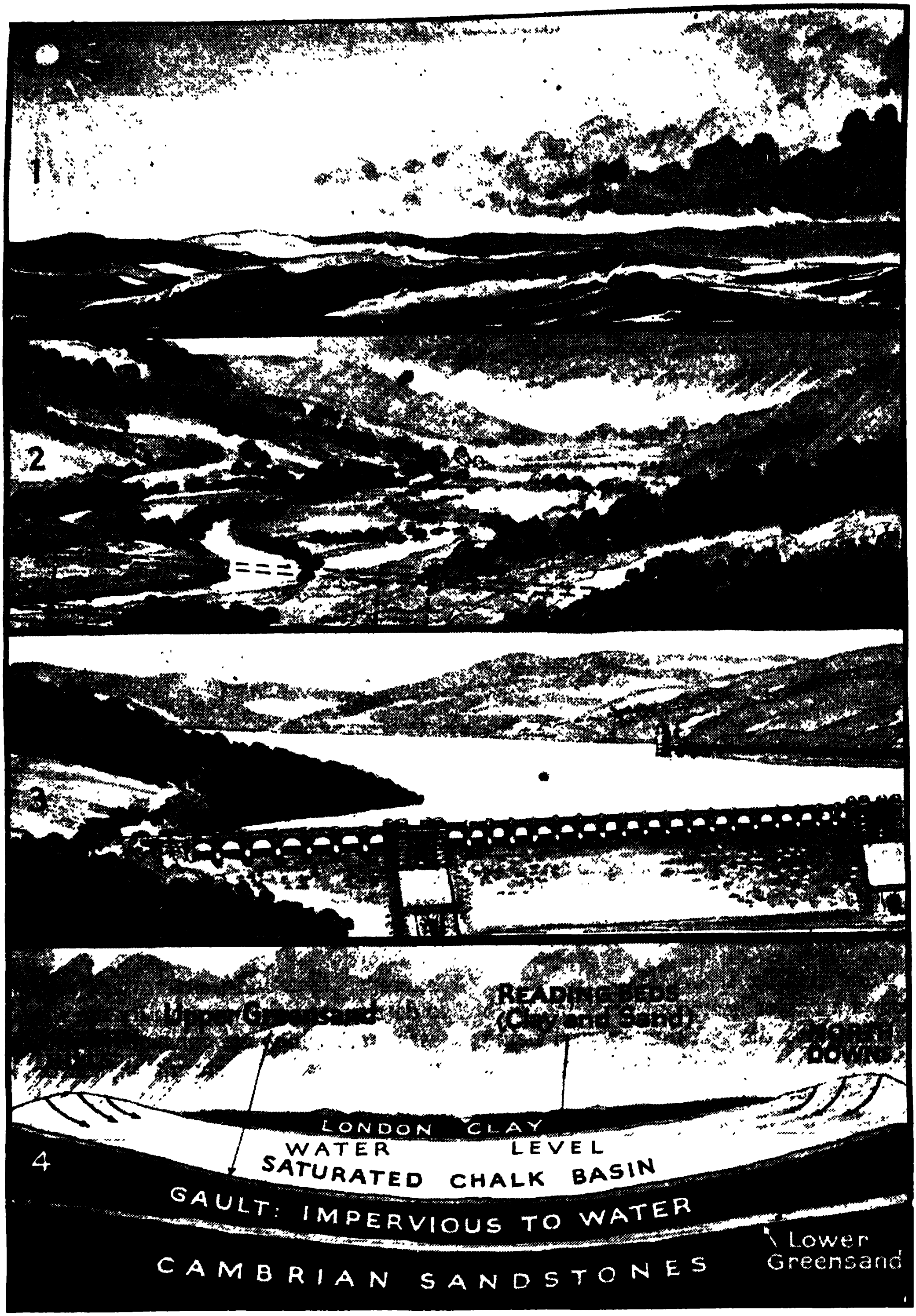
This is a general view of a water-power generating station belonging to the Clyde Valley Electrical Power Company. Though in Britain electricity is generated mainly by heat engines there are some mountainous districts where water power can be used instead of the steam produced by burning fuel

wire made of a special alloy are coiled round a bar of heatproof material, such as fire clay, the bar thus wound being known as an element. A minute or so after the current is switched on these elements begin to glow, and in three or four minutes they are at full heat.

For various other electrical appliances used in the home, such as vacuum cleaners, washing machines, fans, etc., neither light nor heat is required, but power. Therefore each of these has a compact electric motor to operate it.

The radio set is in a category of its own; the current, as it passes through different valves and transformers, serves to detect, modify, and amplify the wireless waves which are constantly passing on their way from transmitting stations.

Modern cable making is a science of itself in which research is constant. Oil-filled cables for underground use contain an oil duct, and the oil, which is kept under pressure, impregnates the insulating material and fills up all air spaces that may form through expansion and contraction. For the overhead lines of the grid bare aluminium wire is used, but for telephone and telegraph work, copper is almost universal.



HOW WATER EVAPORATES, CONDENSES AND COLLECTS

Fig. 1. Sources of water supply: 1, Evaporation of sea water forming rain clouds; 2, River valley in rainy district; 3, Dam at its lower end; 4, Geological section showing chalk basin under London.

HOW WATER COMES TO YOUR TAP

Our natural reservoirs. Wells. Modern methods of water supply. Dams. Aqueducts. Slow filter beds. Quick gravity filter beds. Purity tests. "Water London." Pumping. Service reservoirs. The water mains. Methods of waste detection. Paying for water.

THE great natural reservoirs of water are the oceans. Nature purifies the salt sea water for us and spreads the pure supply over the whole country. Water is evaporating all the time from the surface of the sea and, as it evaporates, it leaves the salt behind. From evaporation, the water is brought back to the earth by condensation (Fig. 1). Clouds are formed in the sky when the air which is saturated with vapour is cooled. That is why mountain tops are often wreathed in cloud. The cold surface of the mountain condenses the vapour in the warm air which comes into contact with it. When the little drops of water which form a cloud come together to make larger drops, rain falls. Some of the rain lies on the surface of the ground and evaporates from there. Some of it is sucked up by plants and trees and evaporates again from their leaves. Some sinks deep into the ground and flows out again as a river in a distant valley. As a river, it eventually makes its way back into the sea. But in all these cases, it evaporates again into the air. The process of evaporation, condensation and re-evaporation goes on continuously.

Springs, streams, lakes and rivers are used by man for drinking. In the heart of the country he can still find a pure natural supply away from dwelling houses. But where rivers flow through towns, they are polluted and unfit for domestic purposes. It is still possible, however, even in cities, to tap some of the pure supply of water that lies deep below the ground and to bring it to the surface by means of wells. If rain falls on porous soil, it will soak through the ground until it reaches waterproof rock. It will then either travel along the surface of the waterproof rock until it flows out into some distant valley, or it will collect into an underground reservoir, unable to escape unless wells are sunk.

There are three kinds of wells, each appropriate to a different geological formation, shallow or deep accordingly.

LONDON'S NATURAL RESERVOIR

Underneath London lies a great reservoir of pure water. It is formed by a big belt of chalk which extends from Hertfordshire in the north to Surrey in the south, coming to the surface in chalk hills in these areas, but sinking to a depth of from 200 ft. to 300 ft. under London proper (Fig. 1). Its surface is not level and in certain parts of central London it comes to within 40 ft. of the surface, while at Hampstead Heath it has 400 ft. of clay piled on top of it.

Into this basin of chalk is piled London clay. Separating it from the clay, however, is a bed of sand about 50 ft. thick and a 70-ft. deep layer of clay, sand, pebbles and shells called the Woolwich and Reading beds. The rain flows

into the chalk where the chalk and sand come to the surface in Hertfordshire, Bedfordshire and Surrey, at 300 ft. or more above sea level. The water flows very slowly through the chalk, but more quickly through the sand belt which helps to distribute the water along the whole chalk level. The belt of hard clay above prevents the water from rising. It therefore collects and saturates the chalk and sand where they lie below sea level.

ARTESIAN WELLS

This great underground reservoir has been tapped by wells sunk right through the clay into the chalk where the chalk surface is well below sea level. A well bored through clay into chalk (Fig. 2) is called an Artesian well, from Artois, in France, where some of the first wells of this description in Europe were sunk. The chalk which is tapped by the well may be so full of water that the water rises of its own pressure high up in the well, and may even overflow.

A third type of well is that sunk to a considerable depth through porous rock extending immediately below the surface in a deep belt. The water in this case is purer than that of shallow wells. It has in all circumstances, however, to be pumped for there is no belt of hard clay above the porous rock to hold the water down and to create that concentration of water which forces it up the borehole. In some cases these wells in the London area are privately owned, having been sunk by individual concerns for their own, mainly industrial, purposes, but today only 16½ per cent of London's public water supply comes from wells.

Modern town dwellers are very lavish with water. This commodity, which was so scarce and of such poor quality less than a century ago, is now taken for granted. Water authorities have to use all their ingenuity to meet a rising demand. Londoners used 34 gals. of pure water per head per day in 1939; in the same year Birmingham's citizens used 32.03 gals., rising to 34.27 in 1941. Other big provincial towns show similar figures. Every year the amount used per head tends to rise. The wells and rivers within a town's own boundaries are insufficient for its modern needs. It has to draw on a wider area for water as its population grows more concentrated.

A glance at the rainfall map shows that the areas of heavy rainfall are to be found remote from the crowded centres of population. The hilly regions of Cumberland, Westmorland and Wales are the natural gathering grounds of water for the congested centres of Central and Western England.

DAMS AND RESERVOIRS

Big cities like Manchester, Birmingham, Liverpool, Cardiff and Swansea, however, have all in turn selected gathering grounds in these hilly regions, and have constructed reservoirs and dammed up natural lakes to meet the heavy demand for water (Fig. 1).

Manchester Corporation has exploited the advantages of a natural lake at Thirlemere, in Cumberland. It has built a great dam across the valley where the water flows out of the lake, thus creating an additional source of over 8,000,000,000 gals.

Liverpool Corporation, on the other hand, has gone to the Welsh mountains for its supply and, instead of turning an existing lake to its own use, has set out to create one. By damming up a valley through which the River Vyrnwy, a tributary of the Severn, was flowing, the corporation created an artificial lake and called the reservoir Lake Vyrnwy. The reservoir has a length of nearly five miles and holds 12,000,000,000 gals.

A gathering ground has been chosen in the Welsh hills by the Birmingham Corporation which in 1893 acquired

45,562 acres of the collecting area of the upper portion of the River Elan. At the same time the corporation took parliamentary powers to construct six reservoirs, with a total capacity of 18,000,000,000 gals. of water.

AQUEDUCTS

The artificial channel along which the water is conveyed from the hills to the towns is called an aqueduct. In earlier days the aqueduct was an open channel like a river. In modern times, however, aqueducts carrying water for domestic supply never contain open cuttings. These are roofed over to prevent contamination of the water. Birmingham's aqueduct is just over seventy-three miles long from the lowest of the chain of three reservoirs to the storage reservoir and filtration plant at the end of it. Half the aqueduct consists of conduit and half of inverted syphon—the U-shaped pipes which are the modern solution of the problem of crossing deep valleys. The conduit section of an aqueduct consists partly of tunnels through the hill-side and partly of "cut and cover," the name for the roofing in of an open cutting (Fig. 3). The conduit may be lined with concrete, faced on the sides and invert with blue brickwork.

FILTRATION

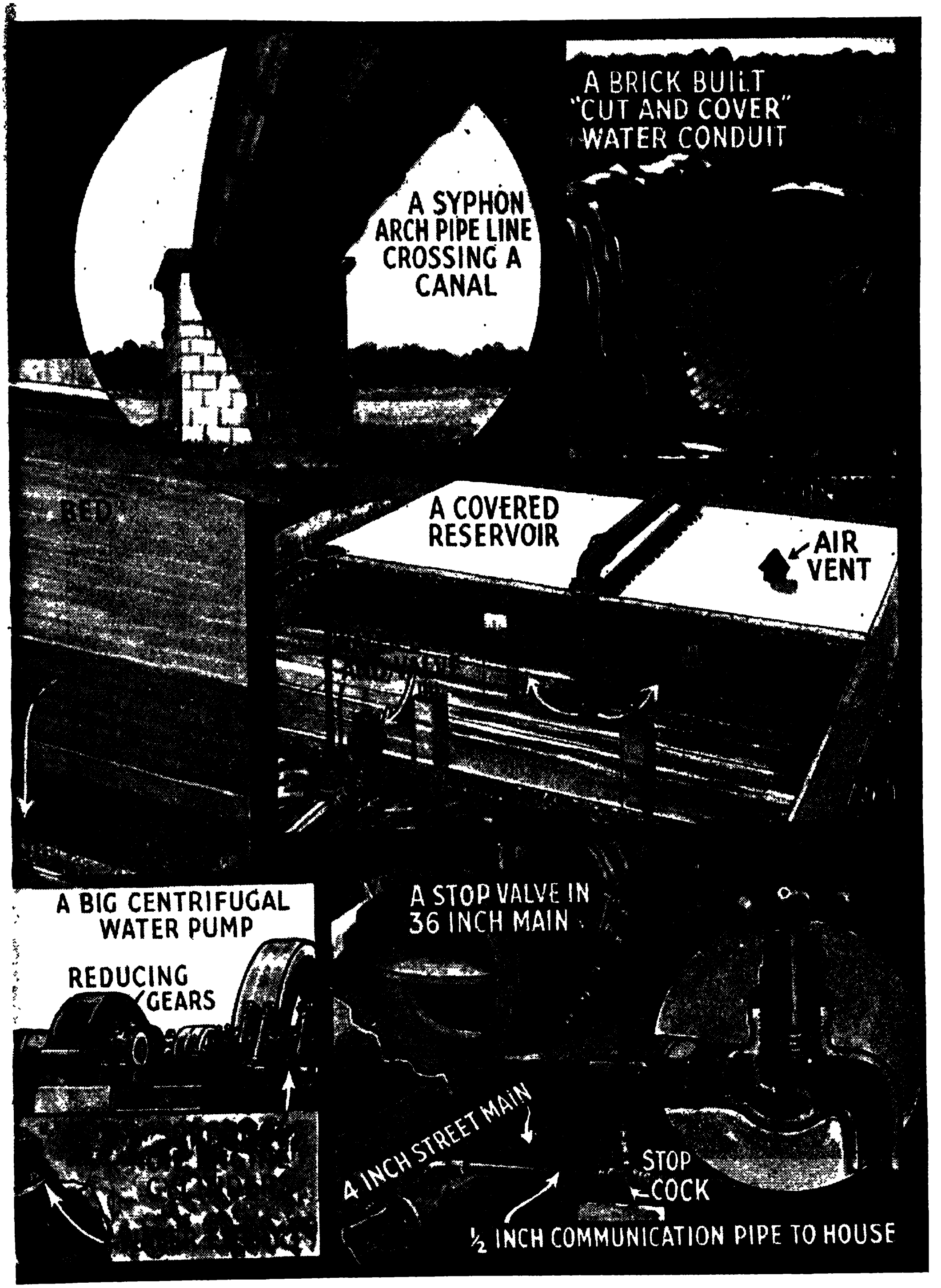
In all modern waterworks provision is made for the filtration of the water before it goes into supply. Even in the case of the pure supply brought from the Welsh hills, filtration is necessary to ensure 100 per cent purity. In Birmingham's scheme the water is filtered after

BORING THROUGH CLAY TO CHALK

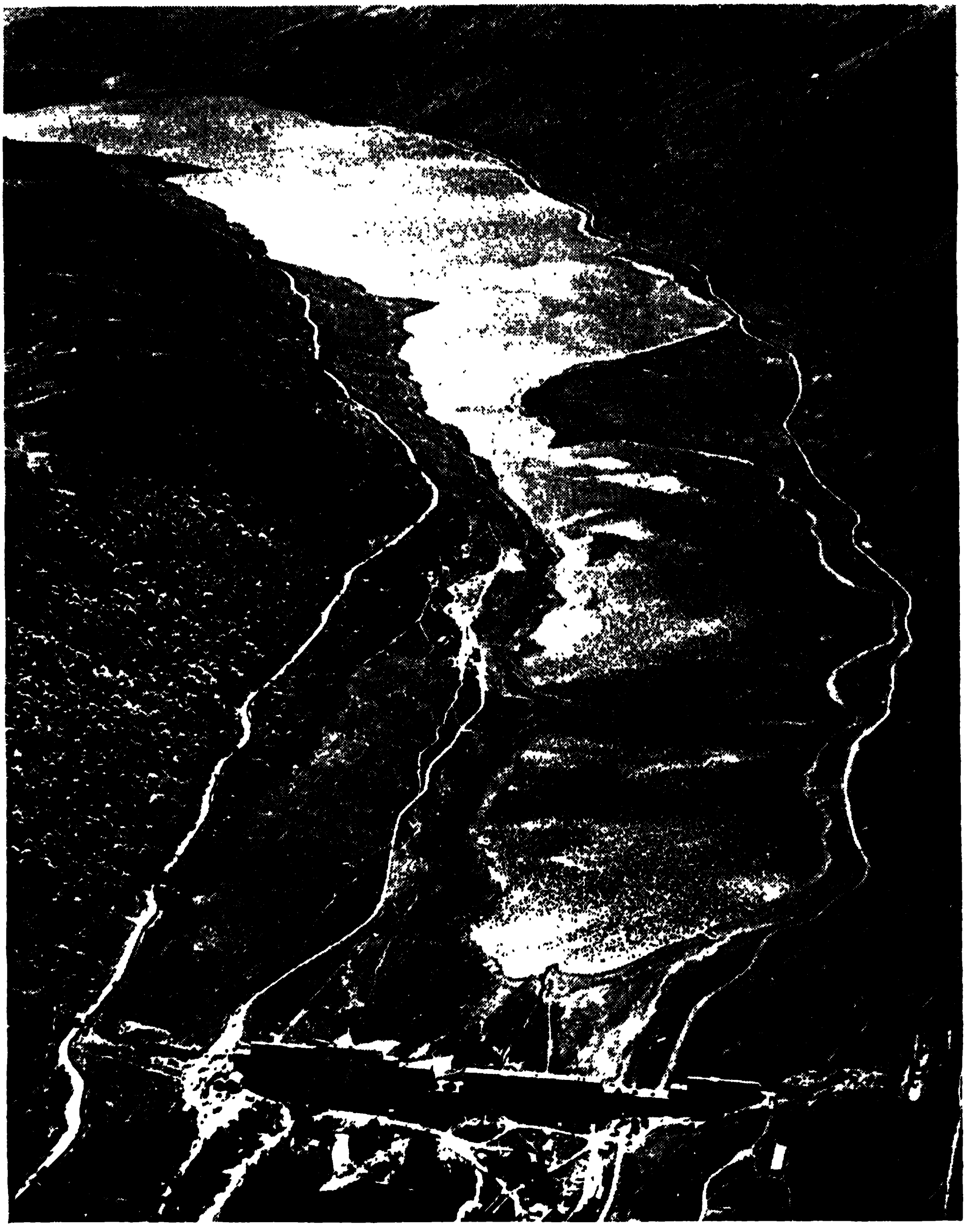
Fig. 2. A 425-ft. artesian well is sunk in London. Here are details of the process and strata. A, Motor-driven air compressor; B, Pipe for air; C, Discharge pipe for water; D, Gravel; E, Blue clay; F, Sand, clay, pebbles; G, Chalk, flints; H, Grey chalk; I, Water; J and K, Enlarged section of air lift pipe for raising water (J, inner pipe for water; K, outer pipe for air); L, Air pressure drives water up the central pipe.

DIAGRAMMATIC SURVEY OF THE PROCESS

Fig. 3. These are some of the stages through which your drinking water passes between river or valley reservoir and your kitchen tap. It is conveyed from a distance by aqueduct, consisting half of inverted syphon—U-shaped pipes—and half of conduit. (There are no open cuttings, the roofing



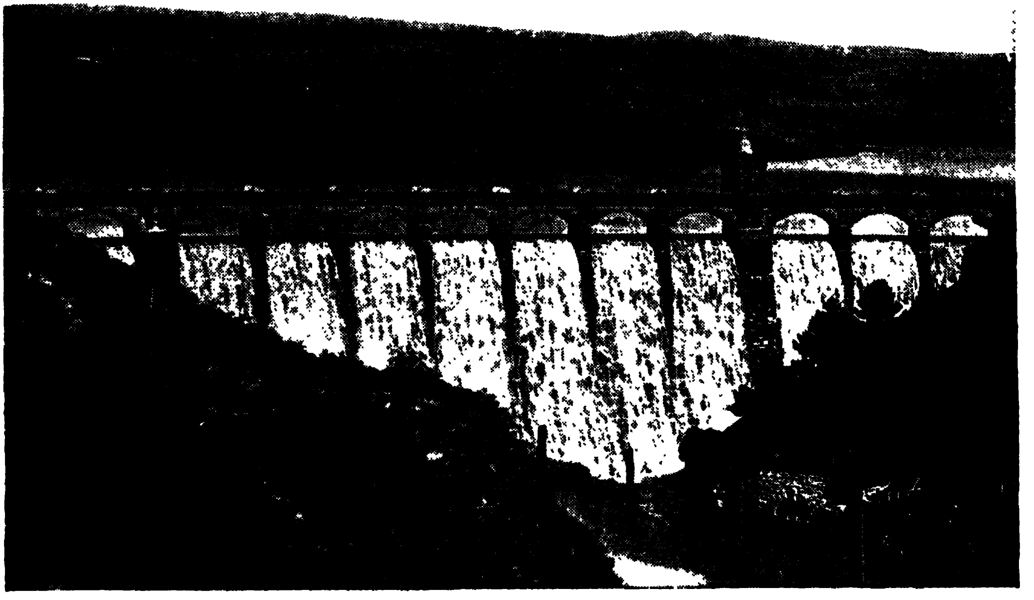
ESSENTIAL TO PROVIDE DRINKING WATER
being called "cut and cover.") It is then filtered by the primary and slow sand bed processes, measured by Venturi meters, and then reaches the reservoirs, which are sometimes covered in as shown. Pumps of great power are used and mains of various diameters bring water to the tap



NEED FOR DRINKING WATER CREATES A MIGHTY ENGINEERING WORK

Hawkeswater Dam in Westmorland is one of the vast undertakings needed to supply Britain's great cities. Here it was decided to extend an existing lake and incidentally submerge an entire village. The cost of this undertaking, designed to free Manchester from any fear of drought, was £10,000,000.

leaving the reservoirs in order to prevent the access of the iron bacteria, present in the raw water, into the aqueduct mains. It is also filtered at the other end of the aqueduct before passing finally into supply. Where, as in the case of London, a



SOURCE OF BIRMINGHAM'S SUPPLY

The photograph shows reservoir at Graig Goch in the Elan Valley where the potential capacity of the many thousand acres acquired by the Birmingham Corporation is 18,000,000,000 gallons of water.

city draws its water from an urbanized river, filtration is vitally necessary.

Filtration is the passing of the water through specially constructed beds which remove all the impurities. There are two types of bed in use today—the quick gravity, or primary, filter, and the slow sand bed. The slow-filter bed is usually about an acre or just under in area and is about 10 ft. deep. It has a floor of concrete slabs resting on breeze concrete. A collecting channel runs across the concrete and is covered by perforated slabs which allow the water to percolate slowly through to the channel underneath. The channel drains the filtered water away to the pumps (Fig. 3). Over the concrete slabs is placed some 2½ ft. of graded gravel and above that 1 ft. of sand. The depth of water on top is kept at 4 ft. The water is fed to the bed very gently so as not to disturb the surface of the sand. The water passes through the beds at the rate of some 2 gals. an hour for each square foot of surface. At this rate a filter bed of an acre delivers about 87,000 gals. an hour of filtered water, 2,000,000 gals. per day.

DOUBLE FILTRATION

The introduction by water authorities in recent years of a method of double filtration has greatly speeded up output. Where great quantities of filtered water are required daily, it is clear that an enormous acreage of slow-filter beds would be required to meet the demand if they were the only filtering medium. Moreover, the slow beds tend to become clogged with a green gelatinous growth, called algæ, which flourishes in river water at certain times of the year. These problems have been met by passing the water through quick gravity filter beds before it reaches the slow filters. These beds also are composed of a layer of sand over a depth of graded pebble, but the process of filtration is speeded up by

AN ARTIFICIAL LAKE IN WALES

Reservoir of Newport, this is an artificial lake in the mountains at Talybont, Breconshire, formed by damming a valley two and a half miles long. Such hilly regions are the natural gathering grounds of water for the congested centres of Central and Western England like Birmingham, Manchester and Liverpool. These and other cities have constructed huge reservoirs and dammed natural lakes.

A MILLION GALLONS A DAY

When the energy of the placid waters, seen above, is released, this is the effect. Water is here shown pouring from great pipes at Talybont, at the rate of approximately a million gallons a day.

the operation of gravity. In London the Metropolitan Water Board has already equipped four of its fourteen filtration stations with primary filters in addition to the slow beds and, where this has been done, the output per square foot per hour from the slow beds has been speeded up from between 1.2 to 2.42 gals. to between 4.86 and 6.15 gals. A primary filter unit is shown in Fig. 3.

whereon feed the microbes which may cause disease. Without food they do not live long or multiply. The disease germs most likely to be conveyed by drinking water are the typhoid bacillus and the cholera vibrio (Fig. 4).

In a modern water undertaking samples of water for testing are taken every day at every works. The water is submitted to two tests: the chemical and the

FILTERS THROUGH WHICH WATER SLOWLY DRAINS

In these slow sand filter beds, impurities are removed from the water. These beds are usually about an acre in area and 10 ft. deep and consist of layers of sand and gravel on a concrete floor through which water drains away to the pumps at the rate of 12 gals. an hour for each square foot of surface. Filter beds cover much ground and are supplemented by quick gravity fillers.

The high tower, which is a feature of the primary filtration plant, is an essential part of its construction. The filter beds are placed at the top of the tower and the water is drawn down through them into an open white-tiled channel which runs down the centre of the building. Already, at this stage, the water is considerably clearer and purer. The bulk of the algal growth has been left in the primary filters which can be quickly cleaned, as they become clogged, by an air scour, followed by an uprush of filtered water (Fig. 3). After leaving the primary filters, the water passes to the slow sand beds for final filtration.

By removing the vegetable and animal matter suspended or in solution in the water, filtration removes the food

bacteriological. The chemical test deals with such questions as the hardness of the water; the most important is the bacteriological test which measures the purity. The method adopted for the detection of impurities is testing for the presence of the *bacillus coli* (Fig. 4). This is a microbe of intestinal origin which is quite harmless in itself, and is present in every human body. It is a very hardy microbe and is adopted as an index of purity because it is more tenacious of life than disease germs and more capable of resisting disinfectants and germ destroyers. If, therefore, only a small number of *B. coli* are present in a water it is certain that it must be practically free from all other bacteria.

The unit most frequently taken for

the examination of water is a cubic centimetre. Bacteriological analyses give the number of organisms present per cubic centimetre when a broth of agar or gelatine is incubated. The standard required in a good water is that on gelatine the number of colonies should not exceed 100 per c.c. *B. coli* should be absent in 100 c.c. Experience has also shown that the effect of storing contaminated water is beneficial.

The attack on disease germs in water takes three forms. The first is the storage of the water in reservoirs, which greatly improves its purity. The Metropolitan Water Board, through its Water Examination Department and fine Laboratory, has made a special study of the effects of storage and has found them to be so beneficial that all its river water is now normally passed through storage reservoirs, although this involves additional pumping in nearly every case.

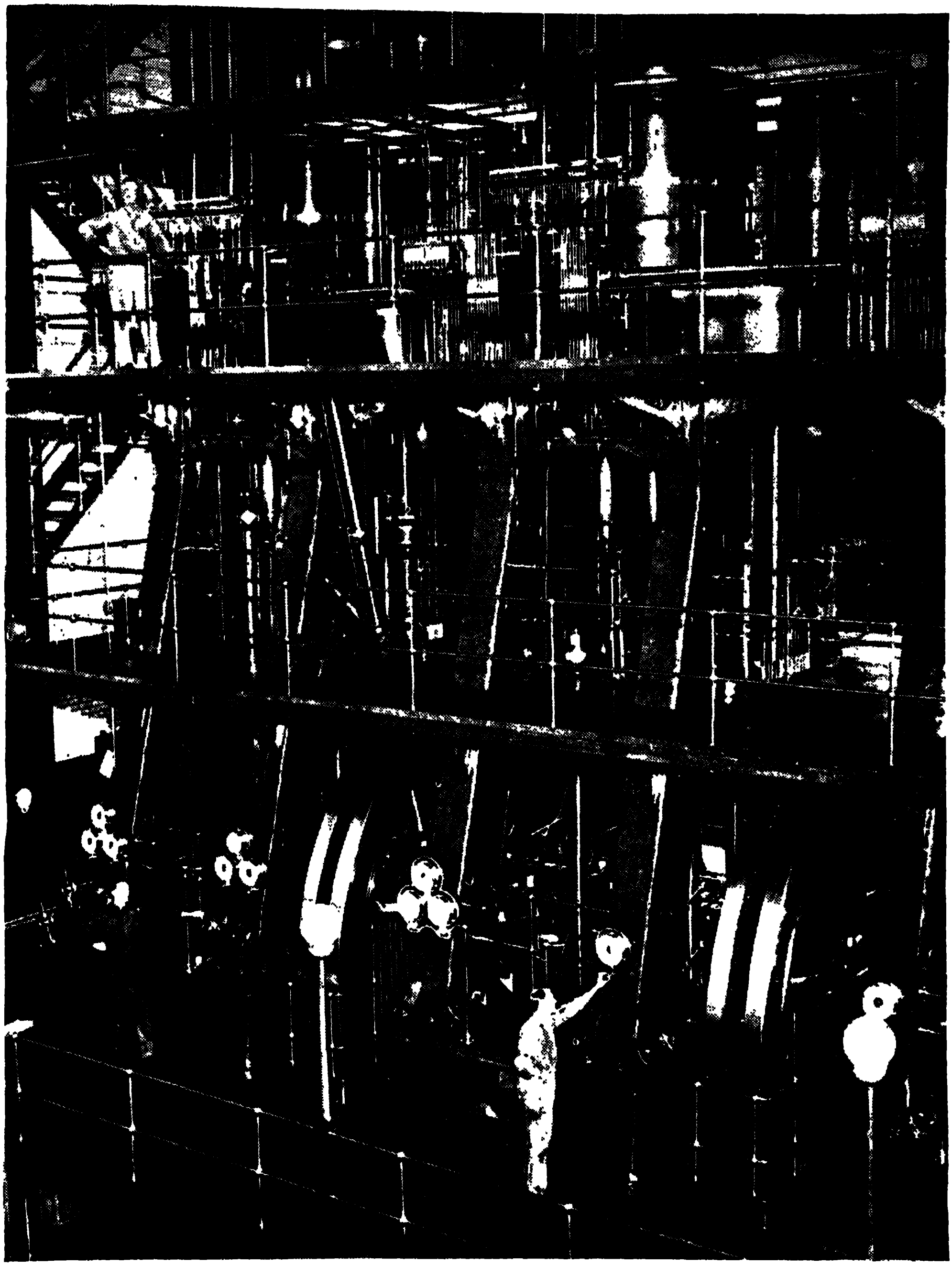
CHLORINATION

From storage the water passes to the filtration beds, described above. Filtration removes some 98 per cent of the remaining microbes. But nothing, in modern times, is left to chance. As a final safeguard London's water is now chemically treated before it passes into supply. The latest practice of the Water Board is to use ammonia and chlorine gas. The chlorine purifies the water and the ammonia offsets the flavour of the chlorine and improves the taste. Since the adoption of this process at all the Board's filtration plants, there has been a marked improvement in the purity of the water. Nearly 99 per cent of the samples of water examined are now free from *B. coli* in 100 cc. The discovery has also been made that copper sulphate greatly reduces the vegetable growths on the beds and, by so doing, increases the output of water from them.

For purposes of water supply, London means an area of 573 square miles and includes the County of London, together with parts of the counties of Essex, Middlesex, Kent, Surrey and Hertfordshire. It contains a population of some eight million people. It is the largest undertaking of its kind in the world, and employs some 6,000 people. One out of every six persons living in Great Britain is dependent for water supply on the Metropolitan Water Board. And every resident in "water London" consumes or uses in a day about twice his weight in water. In the River Thames and its tributary, the Lee, London has a fine natural supply of water "on her own doorstep." In the past five years the consumption of water in the London area has averaged some 300 million gals. daily, of which 65 per cent has come from the Thames.

The places at which water is taken from the river are called intakes. They are channels through which the water is diverted to the storage reservoirs, but, before reaching the reservoirs, the water is measured by Venturi meters (Fig. 3). The measurement of the water at every key point in the cycle of supply is essential for the guidance of the engineer. Moreover, the amount of water which may be drawn from the Thames is limited by Act of Parliament. The Board may not abstract water from the Thames when the actual flow at Teddington Lock is less than 170 million gals. daily, nor when the abstraction would reduce the flow to less than that quantity.

From the intakes the water passes to the storage reservoirs. These form an important reserve in dry periods when the natural flow of the Thames falls below requirements. During the summer months, the Metropolitan Water Board and the neighbouring water companies require some 205 million gals. of Thames-derived water daily. This means



THESE PUMPS ARE CONSTANTLY AT WORK

The pumping station at a large waterworks maintains your supply. London's drinking water depends upon uninterrupted pumping of which there are at least two processes. The raw water has to be pumped into the storage reservoirs and the filtered water has to be pumped into supply. When variations of level occur, as in London, the water is either pumped direct through the mains or into service reservoirs at a height sufficient to give the required pressure. Pumps of great power are needed to pump the filtered water into supply as long distances often have to be covered. Fig. 3 shows some of the constructional features of a big centrifugal water pump.

PRIMARY FILTERS SPEED UP OUTPUT
Water flows down from the primary filter beds at a primary filtration plant. The introduction of the primary filter has greatly speeded up output as an enormous acreage of slow filter beds would be required if they alone were used.

that when the flow of the river at Teddington Lock falls below 375 million gals. per day, the storage reservoirs have to be drawn upon.

The importance of adequate storage facilities is, therefore, very great. In recent years the Metropolitan Water Board has been steadily increasing the capacity of London's storage reservoirs. There are now nine large and forty small storage reservoirs serving "water London." They have between them a capacity of 19,657 million gals. The largest is the "Queen Mary," opened in 1925, which has a water area of 723 acres almost equal to the combined areas of Hyde Park, Kensington Gardens and St. James's Park.

The maintenance of London's water supply is entirely dependent upon uninterrupted pumping. All the water passes through at least two pumping processes.

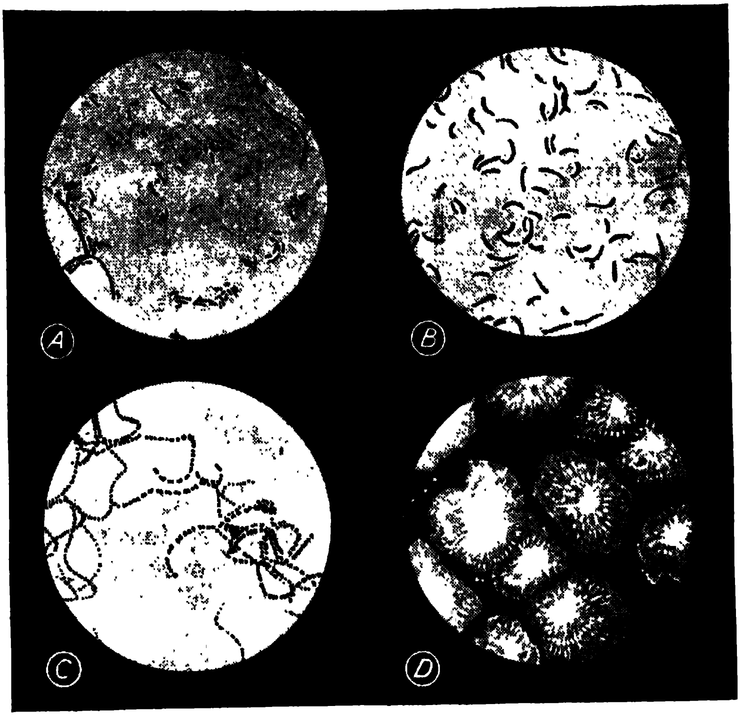
PUMPING PROCESS

The raw water has to be pumped into the storage reservoirs; the filtered water has to be pumped into supply. Pumps of very great power are required for the latter purpose, as in some cases the water has to be pumped long distances (Fig. 3). Trunk mains of up to 48-in. diameter carry the water across London, and under recent schemes, even larger mains are being constructed.

One of the main pumping problems in the London area is the variation in the levels to which the water has to be distributed. The pressure required to supply water to Hampstead Heath would obviously be excessive, and even dangerous, for the low-lying areas round the river itself. This means that the water supplied to the lower levels is pumped to the houses direct from the trunk mains, whereas the water for the higher levels is pumped up into service reservoirs of sufficient height to give the pressure required to force the water to the top of the surrounding houses.

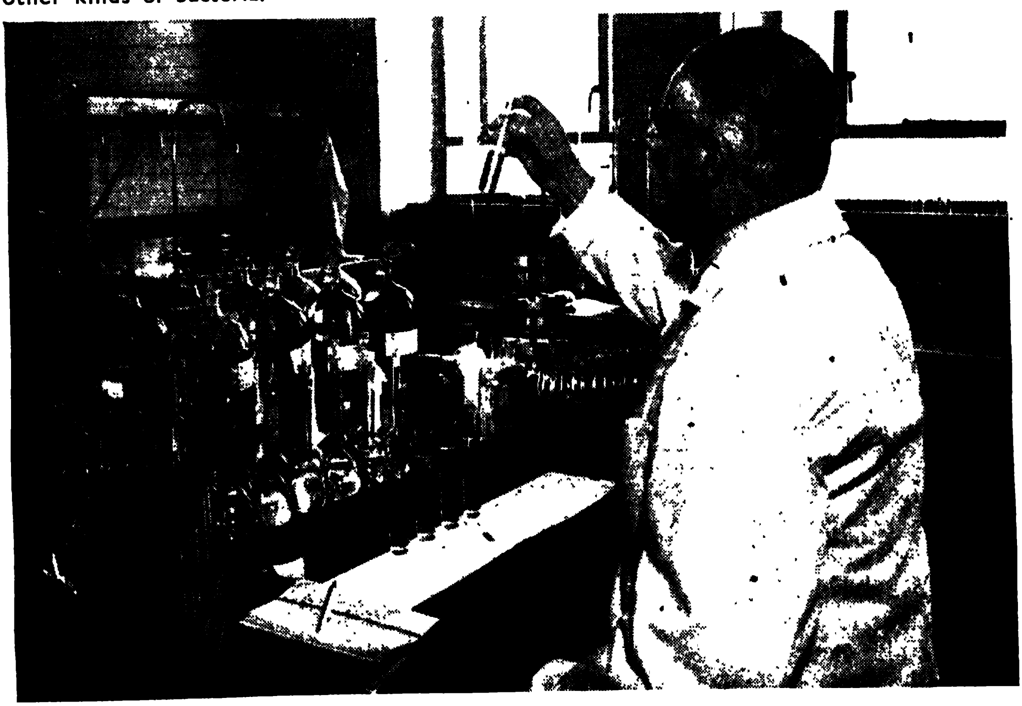
SERVICE RESERVOIRS

Service reservoirs have the advantage of helping to balance the fluctuations in the hourly rate of demand. In a large and busy city such as London, the demand for water during twenty-four hours may fluctuate from 40,000 gals. in the dead hours of the early morning to some 160,000 gals. between 9 a.m. and noon. In a heat wave period the fluctuations may go to even greater extremes. On the



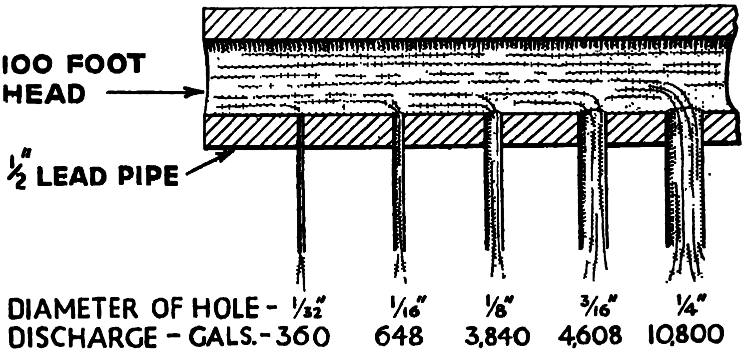
FOUR TYPES OF MICROBE FOUND IN WATER SUPPLY

Fig. 4. Some of the germs which are most likely to be found in drinking water are here greatly magnified. A, Typhoid bacilli x 1,500; B, cholera vibrios (comma bacillus) x 1,500; C, streptococci x 1,300; D, colonies of colon bacillus. In a modern water undertaking samples for testing are taken every day at the works and the method adopted is to test for the presence of the colon bacillus, a microbe harmless in itself, but serving as an index of purity because more tenacious of life than disease germs. When only a small number of the colon bacilli are present it is certain that the water must be practically free from all other kinds of bacteria.



TESTING DRINKING WATER IN THE LABORATORY

In the well-equipped laboratory of the Metropolitan Water Board, shown in our illustration, every safeguard against microbes is devised. A final safeguard is chemical treatment by means of ammonia and chlorine gas. The chlorine purifies the water and the ammonia offsets the flavour of the chlorine. Since the adoption of this process there has been a marked improvement in the purity of the water.



HOW A SMALL LEAK WASTES A LOT OF WATER

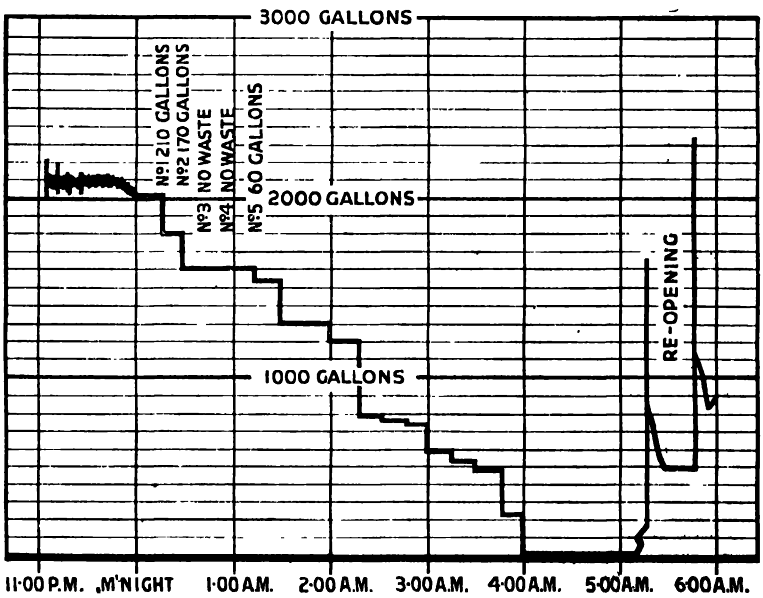
Fig. 5. A minute hole in a half-inch lead pipe can cause a loss of 360 gals. a day, a quarter-inch hole a loss of 10,800 gals. daily.

purposes into a network of areas called pressure zones. Each of these has to be served by water at a different pressure, and this means separate mains in each case, and sometimes even separate pumping stations. Service reservoirs at differing levels help to supply the various pressures required.

evening of June 11, 1933, the demand in London rose to a record peak of over 170,000 gals. an hour round about 9 p.m. dropping again to some 48,000 gals. an hour in the early hours of the following morning. Where the water to meet this demand is coming through service reservoirs, the reserve which has been built up in these reservoirs during the quiet hours of the night can be used to meet peak demands during the day.

Unfortunately, large parts of the London area are too low lying to make the introduction of service reservoirs practicable. On the other hand, areas of considerable height have also to be served. The variation in levels is as great as 400 ft. London is therefore divided for distribution

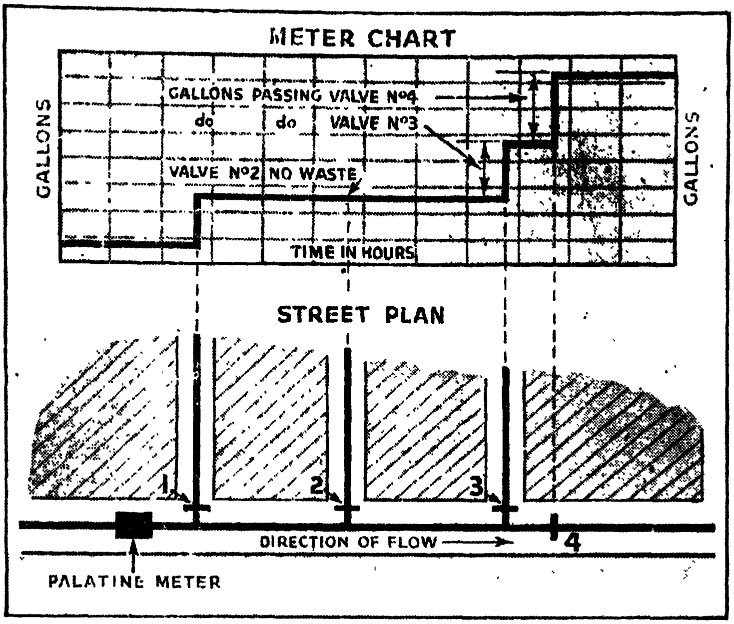
Carrying the water from the pumping stations to the premises served is a network of mains which honeycombs the sub-soil of London's streets. The Metropolitan Water Board owns no less than 8,000 miles of mains which vary in size from 48 in. to 2 in. Of these, the largest



CHARTING THE WASTAGE OF WATER SUPPLY

Fig. 6. This diagram is produced by a waste water meter showing valve inspection with valve shut off. The number of gallons passing is written in vertically. This is one of the methods employed by the waste detectives of the Water Board to track down both leakages and the waste caused by faulty taps or taps left running. A waste detecting meter is placed on the main. By shutting off the necessary valves the amount supplied to the district in question is recorded by the metered main.

proportion consists of 4-in. mains (Fig. 3) which branch off from the trunk mains to serve the side streets. From the street main a ½-in. lead communication pipe branches off under the pavement and the garden path to the house, and up the front of the house to the cistern at the top. Some 18 in. from the garden wall or, if the house is flush with the pavement, from the house wall, is a stopcock. The Board's responsibility for the upkeep of mains covers the communication pipe up to the stopcock. Beyond there the responsibility becomes the householder's instead of the Board's.



TRACKING DOWN THE SOURCE OF THE WASTAGE

Fig. 7. The valves on the branch mains of a waste district are shut down and the time at which each is shut is noted. Thus the effect of shutting down the branch main serving a particular street can be followed on the chart. The work is done in the early morning when the usage of water is practically nil and the effect of shutting down each main should be a small steady drop in the flow. Where it is sharp and sudden the time at which this occurred is ascertained from the chart and thus the street in which it occurred can be identified.

In order to localize the effects of bursts or other damage which may occur to water mains, they are provided with valves at frequent intervals. A valve is a screw which, when turned by means of a key, lets down a paddle, or door, across the main, shutting off the water (Fig. 3). A stopcock is a mechanism for shutting off the water in the smaller pipes. It is less complex than a valve, because it deals with a small ½-in. or 1-in. pipe instead of a large main.

The men who are responsible for shutting off the water are called turncocks. Theirs is a very responsible job for they have to know where to find every valve and stopcock on their walks or areas, and be ready to close them in case of emergency with all possible speed. They must, therefore, reside on their walks, and their premises must never be left unattended. There are 220 turncocks' walks in London, and a turncock may have under his control anything from 1,000 to 2,000 valves.

Loss of water through waste is a very serious factor which every water authority struggles to combat. In London something like a quarter of the water produced never reaches the consumers owing to small leakages on the way. A hole of $\frac{1}{32}$ in. in a ½-in. lead pipe can cause a loss of 360 gals. a day; a hole of ¼ in. causes a loss of 10,800 gals. daily (Fig. 5). To track down such leakages, and also the waste caused by faulty taps or taps left running, the Water Board employs a staff of what may be called waste detectives.

If waste is to be detected it is essential

USING THE WASTE WATER METER
Inspector of a water company uses a waste water meter. In addition to taking the record previously described the inspectors also make use of a stethoscope—a long bar with a microphone at the top. By putting their ear to the microphone they can detect any unusual flow.

to be able to isolate each waste district, or district selected for survey, by means of valves. A waste-detecting meter is placed on the main which brings the supply into the waste district. By shutting off the necessary valves, it is possible to make all the supply required for the district go through the metered main and the meter draws the flow on a chart as indicated by Fig. 6.

SHUTTING DOWN A BRANCH MAIN

The next step is to shut down in turn the valves on the branch mains within the waste district. The time at which each valve is shut is noted (Fig. 7). Thus the effect of shutting down the branch main serving a particular street can be followed on the chart. As the work of detection is done in the early hours of the morning, when the usage of water is practically nil, the effect of shutting down each main should be to record on the chart a small, steady drop in the flow. Where the drop is found to be sharp and sudden, the time at which this occurred is ascertained from the chart and in this way, the street in which it occurred can be identified. Such a sharp drop indicates that an excessive usage of water was taking place before the valve was shut, and that this was probably due to leakage. The next day, therefore, the waste detectives call at all the premises in the street trying to trace the exact spot from which the leak comes

WASTE-DETECTIVES' STETHOSCOPE

If the daytime visits are still unsuccessful, another night search is made—this time with a stethoscope. A stethoscope is an instrument for magnifying sound. It consists of a long bar with a microphone at the top, and the detectives place it on each stopcock in turn where these lead into the houses. By putting their ear to the microphone they can hear if water is flowing at any point where it should not be.

The complicated mechanism of water supply is very costly. This service is treated lightly by those who benefit from it, but, in order to make it possible, millions of pounds have to be spent and thousands of men employed. The householder pays for his domestic supply through a water rate. That is to say, he pays a percentage of the rateable value of his property, regardless of what he consumes. In the United States domestic as well as non-domestic supply is metered. In this country we prefer to treat domestic water supply as a social service, paid for by rate, as is refuse collection or sewage disposal, and otherwise being given freely though a non-domestic supply may be metered.

HOW YOU GET YOUR HOUSEHOLD HOT WATER

A model hot-water system. Methods of construction. Hard-water districts. The direct and indirect systems. Secondary circulation. The boiler and types of fuel Storage and non-storage heaters. Faults and their remedy.

THE working of your hot water system depends upon the fact that water, when it is heated, like most other substances, will expand (actually it contracts as its temperature is raised from freezing point, 32 degrees Fahrenheit to 39 degrees Fahrenheit, but as it expands normally as the temperature is raised beyond this point this fact will not affect us). As the water expands it will occupy more space, and therefore will become lighter in weight (in other words its density will be reduced), so that the higher its temperature, the smaller its weight for a given volume.

A MODEL HOT WATER SYSTEM

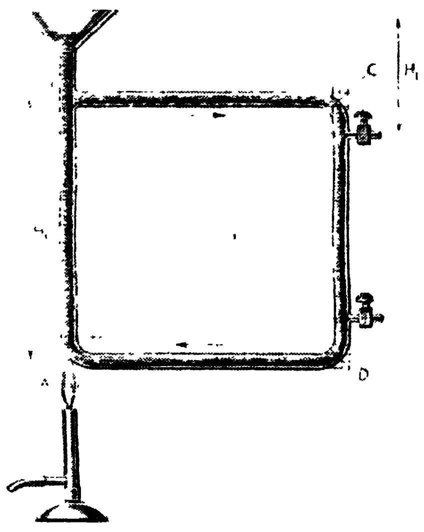
Let us begin by constructing a model hot water system, as shown in Fig. 1. We will use glass tubing, arranged in the form of a square, with a funnel at the top for filling it with water. We have two taps for drawing off the hot water.

If we now apply heat at one bottom corner, as shown, thus raising the water in the vertical column A B to a temperature greater than that in the opposite vertical column C D, its weight per unit volume will become less with the result that the hot water in the left-hand tube will rise, and that in the right-hand tube will fall, and this movement will continue until the weight of the water is the same in each tube.

Thus we have a movement of hot water along the top tube from B to C, and also along the bottom tube from D to A.

If we leave our burner in position, however, as the cooler water reaches A it is heated up, and at the same time the hot water passing from B to C will cool as it has now moved away from the source of heat, therefore the weight in the two columns will never balance and we will get a continuous circulation of the water in the direction shown by the arrows in our illustration.

If we open the tap near the top of the



A MODEL HOT-WATER SYSTEM

Fig. 1. As water is heated it expands. When heat is applied to the corner of the tubing shown, the water in AB rises and the water in CD falls and a circulating movement of hot water is set up from D to A and B to C

right-hand tube, water will flow from it, because the pressure inside the pipe is greater than that outside.

If we open the bottom tap we find that the water will flow from it with greater force than it did from the higher one which appears to indicate that the pressure inside the tube at this point is higher still. This is what we would expect, because the pressure is actually due to the height of water above the tap concerned, and will be governed by the level of the water in the funnel.

THE TWO WATER LEVELS

When water flows out of the taps it will be necessary to pour more cold water into the funnel to keep the tubes full. If this is not done, the water will soon fall to the level of the lower tap. The burner would then soon boil away the water which was left, leaving the tubes dry. When this happens (and it can happen in *your* hot water system) the heat of the burner would melt the tubes, as they no longer have water inside to keep them cool, and we should then have to send for the plumber.

We have already seen that water expands on heating, therefore, if we fill the funnel to the top in the beginning, then when we heat it up, it will expand and overflow. We must, therefore, only fill it up to the level of the lower line, so that there is room left in the funnel to take up the increase in volume due to expansion, then when the water is hot it will have risen to the higher line.

Our simple model possesses a number of deficiencies, so now that it has served its purpose we will put it aside and have a look at a hot-water system of the type generally installed in a small house.

The system should be so arranged that the hottest water will flow out of the taps, and also that as we heat up the water we can store it for use as and when required. It will also be necessary to arrange for fresh cold water to be added automatically when hot is drawn off.

Fig. 2 is a diagram of a simple hot-water system. As shown the water is heated in a back boiler behind an ordinary fireplace, or at the back of a range.

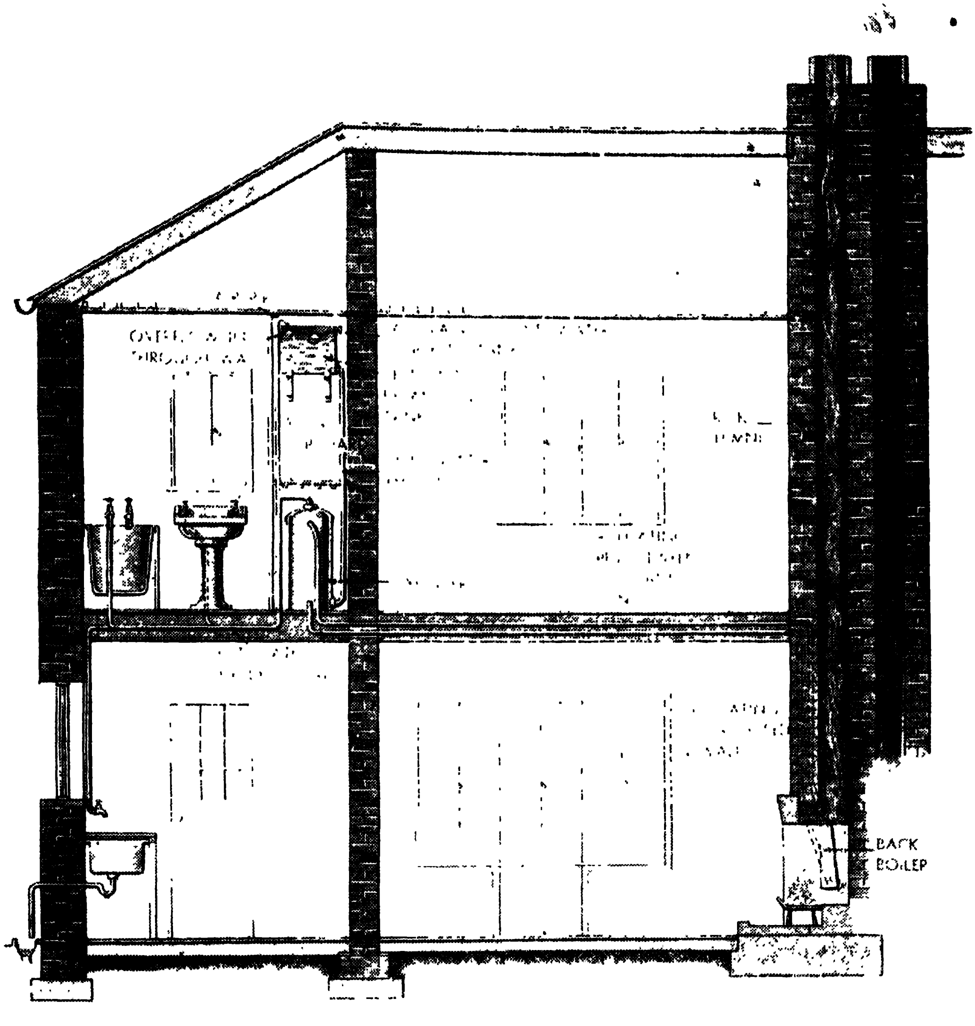
A SIMPLE HOT WATER SYSTEM

A cylindrical tank, generally simply called a cylinder, is fixed above the boiler, perhaps near the ceiling of the same room, or in a linen cupboard on the floor above, where its heat may be used for drying purposes. We use a cylinder because it is able to withstand pressure better than a rectangular tank although when the pressure is low these are often used. Above the cylinder, generally in the roof of the house, we fix a tank, containing a ball valve, to which the water supply from the mains is connected. The boiler, cylinder and cold water tank are connected together by means of pipes as shown.

KEEPING THE SYSTEM FILLED

Cold water enters the tank through the ball valve, and the hot-water system is thus filled with cold water. When water is drawn off, the level in the tank falls and the ball valve opens to admit more water, keeping the system filled. As in our model, we arrange the ball valve so that we do not fill the tank right to the top with cold water, but leave sufficient space to allow the water to expand when heated. However, as a precaution, we fit an outlet pipe near the top of the tank, so that if the water does get too high it will overflow through this pipe, before it can spill over the top of the tank and damage the ceiling. This overflow pipe will, of course, go through the roof or wall, and discharge the surplus water without causing damage.

The fire is lighted, and the water in the boiler heats up. Circulation of the water will commence, slowly at first,



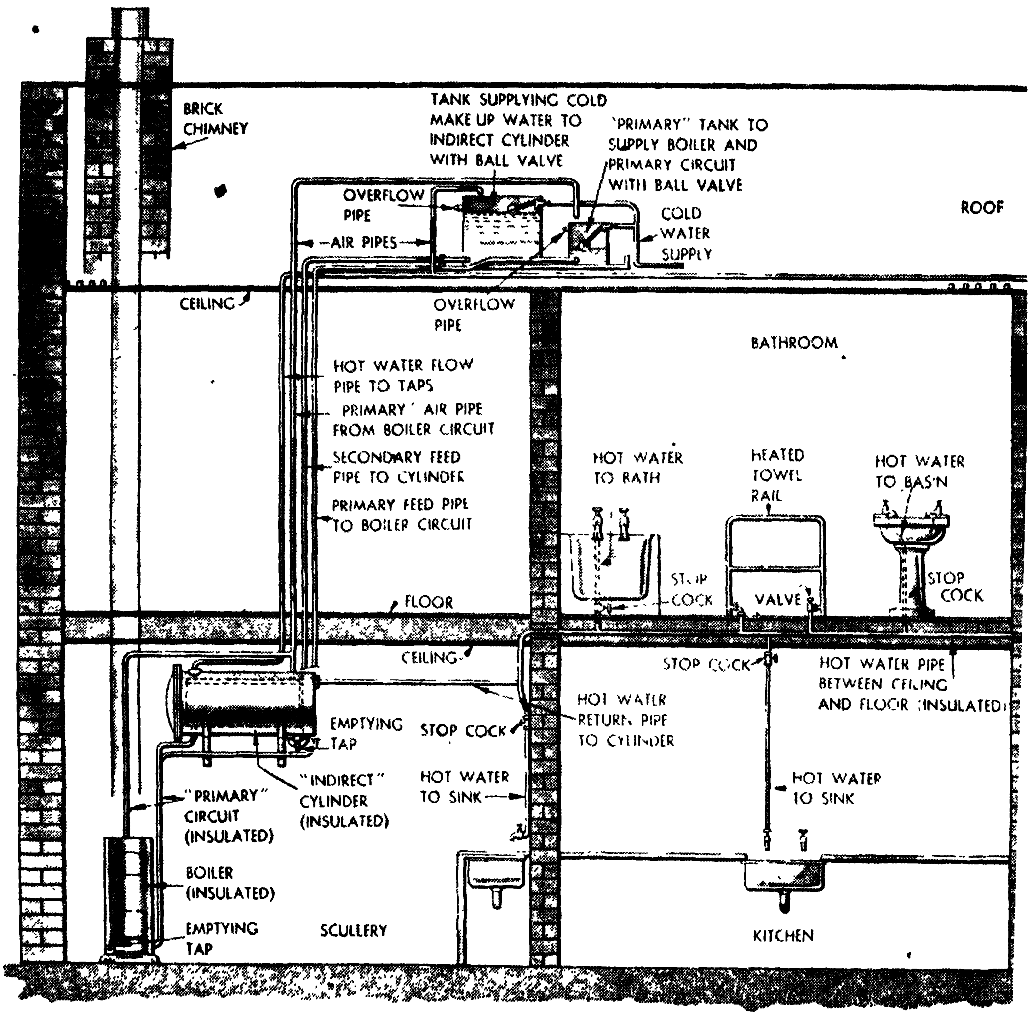
PLAN OF A SIMPLE HOT-WATER SYSTEM

Fig. 2. **The water is heated in a back boiler. A cylindrical tank is fixed above the boiler and above this a tank supplying cold water. When the fire is lighted circulation begins between boiler and cylinder. Hot water collects at and is drawn off from the top of the cylinder to supply the taps.**

between the boiler and the cylinder. As the temperature of the water rises, this circulation will become more rapid. The hottest water, being lightest in weight, will collect at the top of the cylinder. The cold water from the tank is taken into the bottom of the cylinder from where, being heaviest, it will find its way down to the boiler.

We thus gradually build up a storage of hot water in the cylinder, and we should remember that the hottest water will always be at the top. We must, therefore, arrange the system in such a way that the water for the taps will be taken from the top of the cylinder. This is shown in the sketch.

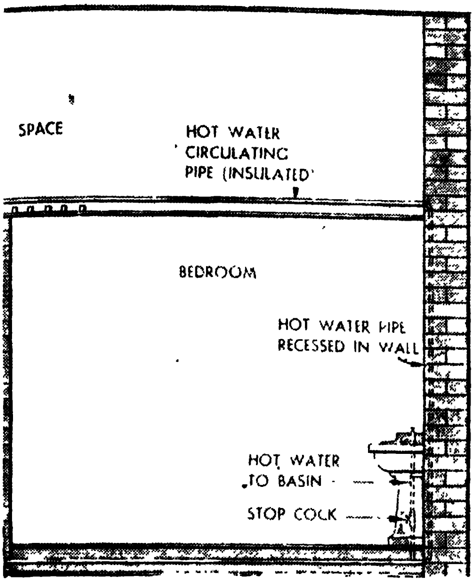
You will also see, connected to this pipe and carried up to above the level of the cold water tank, an air pipe. We filled up the system by introducing cold water into the bottom of the cylinder.



It would be impossible to fill up the system with cold water as air would be trapped in the top of the cylinder, and could only escape through the taps if we did not have this open-ended pipe taken from the highest point, to allow the air to escape. Also, since after the system is filled more air will be carried into the system with the cold water from the tank, all the pipes must be arranged so that air collecting in them will be able to escape through this air pipe.

At the lowest point in the system there is a valve for emptying out the water, should it be necessary to do so.

You may think that it would have been better to connect the cold water pipe from the tank into the boiler and not into the cylinder as we have done, as this water would then not cool some of the water in the cylinder, and would, perhaps, by going straight into the boiler, be heated up sooner. If we did this, however, the cold water entering the boiler would impinge on the hot plates and cause them to contract suddenly, thus setting up strains in the metal and in time the plates would crack. As we have arranged it, the cold water mixes with the hotter water in the bottom of



AN INDIRECT HOT-WATER SYSTEM

Fig. 3. Here we have two cylinders, one inside the other, the inner one having double walls. The main body contains water for supplying taps, whilst water from the boiler is circulated between the double walls. In this way, water from the boiler indirectly warms that in the cylinder. The same small quantity of water is continuously circulated between the boiler and the cylinder, and as hot water is drawn off the system, cold water enters the bottom of the cylinder from an overhead tank as before, but is heated in the cylinder instead of having to pass through the boiler. The pipes between boiler and cylinder are called the primary circuit and those between the cylinder and taps the secondary circuit.

the cylinder before passing to the boiler, and so we avoid this trouble.

If you live in a hard-water district you will probably get deposits of scale in your boiler pipes and cylinder, and in this case your hot-water system should be arranged in such a way that these may be easily cleaned out periodically.

The greatest deposit will, of course, take place on the hottest surfaces in contact with the water, that is, in the boiler. This is not serious in the case of small boilers of the type now being discussed, as the temperature of the fire, to which the boiler plates are exposed, is not great, but even in the case of small private houses in hard-water districts it is better to use an independent boiler provided with proper cleaning doors. In the case of larger systems, such as you may find in large private houses, or in hotels, schools and other large buildings, where the fuel is burned in comparatively large boilers at a very much higher rate, and with a very intense chimney draught and consequently a very much higher furnace temperature, this becomes a serious drawback, and one against which precautions need to be taken.

HOW SCALE DEPOSITS WASTE HEAT

In large systems, water may be used at a very high rate, and if it is hard, thick deposits will soon build up inside the boiler, particularly on the parts exposed to the direct heat of the fire. These deposits act as an insulating film and prevent the heat from passing through the boiler walls from the fire to the water. Apart from the waste of heat due to this, the metal parts of the boiler exposed to the fire are no longer kept cool by the water on the other side which is now separated from them by a layer of non-conducting material. The result of this is that the plates become very much overheated, perhaps even red hot in bad cases, and the ultimate result of this can only be one thing—cracking and distortion of the boiler plates, with consequent leaks—and a new boiler.

In these cases, special boilers are used having a number of cleaning holes with removable covers, giving access to the inside of the waterways of the boiler to enable it to be cleaned out easily when it has been emptied of water.

A better solution of the problem, however, would be to arrange the system in such a way that the same water is circulated through the boiler all the time, and that no fresh water can enter it; in other words, we must heat up our water

without letting it pass through the boiler. But how can we do this? Quite easily. By adopting what is known as the indirect system, the arrangement of which is shown in Fig. 3.

THE INDIRECT SYSTEM

Here, in place of the storage cylinder which we previously used, we have an indirect cylinder, which actually consists of two cylinders, one inside the other, the inner one having double walls. The main body of the cylinder contains the water for supplying the various taps, etc., whilst the water from the boiler is circulated between the double walls of the internal cylinder. In this way the water from the boiler indirectly warms the water contained in the cylinder, by the conduction of heat through the metal walls of the cylinder.

We therefore circulate the same small quantity of water continuously between the boiler and cylinder. and as hot water is drawn off the system, fresh cold water enters the bottom of the cylinder from an overhead tank as before, but on the other hand is heated in the cylinder instead of having to pass through the boiler.

The pipes between boiler and cylinder we call the primary circuit, and those between the cylinder and the taps are called the secondary circuit.

PRIMARY AND SECONDARY CIRCUITS

It will be seen that a small additional tank is now required to fill the primary circuit and the boiler with water. This is provided with a ball valve, although once filled, very little fresh water will need to be introduced.

You will notice something else about our diagram of an indirect system. The hot-water pipe from the cylinder to the taps is in the form of a closed circuit, leaving the top of the cylinder, travelling round the building to the points where hot water is required, and then returni back to the cylinder. The pipe is con nected to the cylinder at one end.

We will, therefore, obtain a circula tion of the water round these pipes. (You have already seen how this happens.) This pipe will be carried as close *as possible to all the taps so that the connexions between this pipe and the* taps are in no cases more than a few feet long, and the nearer the better.

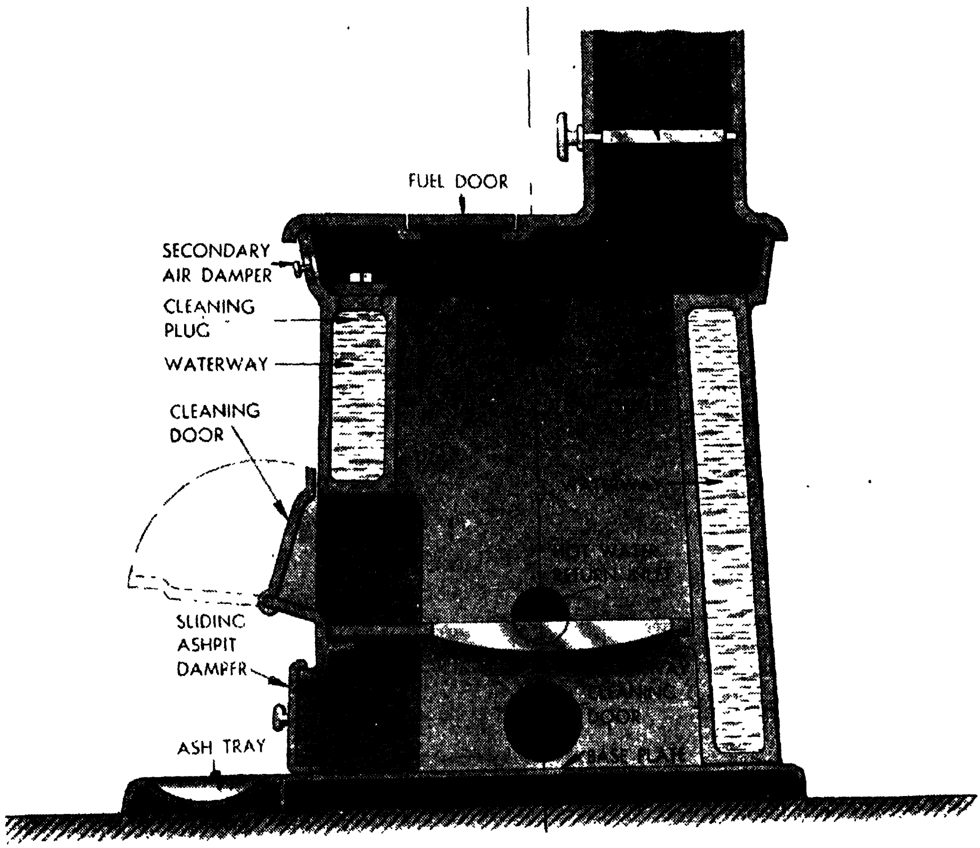
Actually, if we are dealing with a large building, this circuit may branch into several sub-circuits, each going round a different section of the building, and all collecting together again to return to the cylinder.

The reason we did not do this in our first direct system was simply because the taps were not far from the cylinder. If they had been farther away we could have had a secondary circulation, just as we have with the indirect system we are now considering.

SECONDARY CIRCULATION

This secondary circulation ensures that there is always a supply of hot water close to each tap. If we simply have a single pipe to the taps, the water standing in this pipe will soon cool when no taps are in use, so that when you do open a tap you may have to run off a considerable amount of cold or tepid water before you get any hot water. If this happens every time, a considerable wastage of water, and fuel, will result in addition to the inconvenience which it causes. Consequently, and unless the taps are quite close to the storage cylinder, we always have a secondary circulation. It will be seen that we have also connected a heated towel rail to the circulating pipes.

A stopcock has been shown on each of the branch pipes from the circuit to the tap. This is to enable any branch to be shut off independently so that the



HOW THE DOMESTIC BOILER WORKS

Fig. 4. A boiler of the type constructed for burning coke or anthracite will generally burn slowly for up to six hours with one charge of fuel, though, if a large quantity of hot water is needed, the fuel must be burnt more quickly. The rate of combustion is varied by the adjustment of dampers, one in front of the boiler to control the air supply passing through the grate to the fuel, and one in the outlet of the chimney to control the draught. These two dampers have to be regulated in conjunction with one another so that a plentiful supply is always available without overheating.

taps may be rewashered. If we did not do this we should have to empty the water out of the system every time we wanted to put a new washer on a tap.

The cylinder in our indirect system is lying on its side, whereas in our previous system it stood upright. This, of course, has nothing to do with the type of system; it can be installed whichever way is the most convenient.

Very often it will be fixed in a linen cupboard, so that its heat may be utilized for drying purposes. If this is not done, then it should be covered with heat-insulating material, to prevent waste.

No mention has so far been made of the most desirable temperature at which the hot water should be supplied by the taps. A hot bath is usually taken at 100 degrees to 105 degrees Fahrenheit, so the water for washing purposes only need be very little above this temperature so that only a little cold water needs to be added. For washing up greasy plates the water should be rather hotter than this, a temperature of about 130 degrees Fahrenheit being satisfactory in private houses. So if the water is

stored at a temperature of about 130 degrees Fahrenheit and the draw-off is arranged so that the kitchen sink receives the hottest water, satisfactory service will be given by the system. It is always desirable to keep the temperature of the water as low as possible consistent with proper service as by so doing fuel is economized and in the case of hard-water districts the lower the temperature can be kept the less scale is formed.

TYPES OF FUEL

Coal and coke are still the most universally used fuels, though gas and electricity are also used, and possess many advantages. Bituminous coal is burnt in open ranges, coke in special boilers.

There are a large number of domestic boilers now on the market, specially constructed for burning coke or anthracite, varying in size from those suitable for a four- or five-room house, which will stand in the kitchen or scullery, to types suitable for very large houses, hotels and similar buildings, which have to be provided with a special boiler house for themselves.

These boilers will generally burn slowly for up to six hours, or even longer, with one charge of fuel. If a large quantity of hot water is wanted, then, of course, the fuel must be burned much more quickly than this. The rate of combustion is varied by the adjustment of dampers, one in the front of the boiler, to control the air supply passing through the grate to the burning fuel, and one in the outlet to the chimney, to control the effective draught, or pull, of the chimney (Fig. 4). These two dampers should be regulated in conjunction with each other, according to the demand for hot water, so that there is always a plentiful supply of hot water available, without undue overheating which may cause the water to begin to boil.

With the larger types of boilers, one or both of these dampers can be controlled automatically so as to maintain a constant water temperature in the boiler without any attention. This may be done by means of a lever connected to the damper and moved by means of a heat sensitive device immersed in the boiler water (Fig. 5). One popular type of damper regulator consists of a bulb containing automatic bellows and a liquid which expands and contracts as the temperature of the water rises and falls. The expansion of the liquid compresses the bellows, the movement of which gradually closes the damper. Thus, as the water temperature rises, the damper gradually closes, and vice versa, so that by this means the temperature of the water is maintained fairly constantly at any required figure.

Another means of control is by the use of a thermostatically controlled switch. In this case an electric switch is operated by means of a heat sensitive device in such a way that the switch will open or close, whichever is required, when a certain temperature is reached.

HEATING BY GAS

With gas the hot-water system will be exactly the same as one for burning coke, with the exception that the boiler will be of a different type, specially made to burn gas, and it will have a number of gas burners in place of the grate in the coke boiler. The internal construction of the boiler will be rather different from that of the coke boiler, so that the maximum amount of heat from the gas burner is absorbed by the water. The chimney need not be so big. You may use a gas storage heater which embodies a gas heater and storage space.

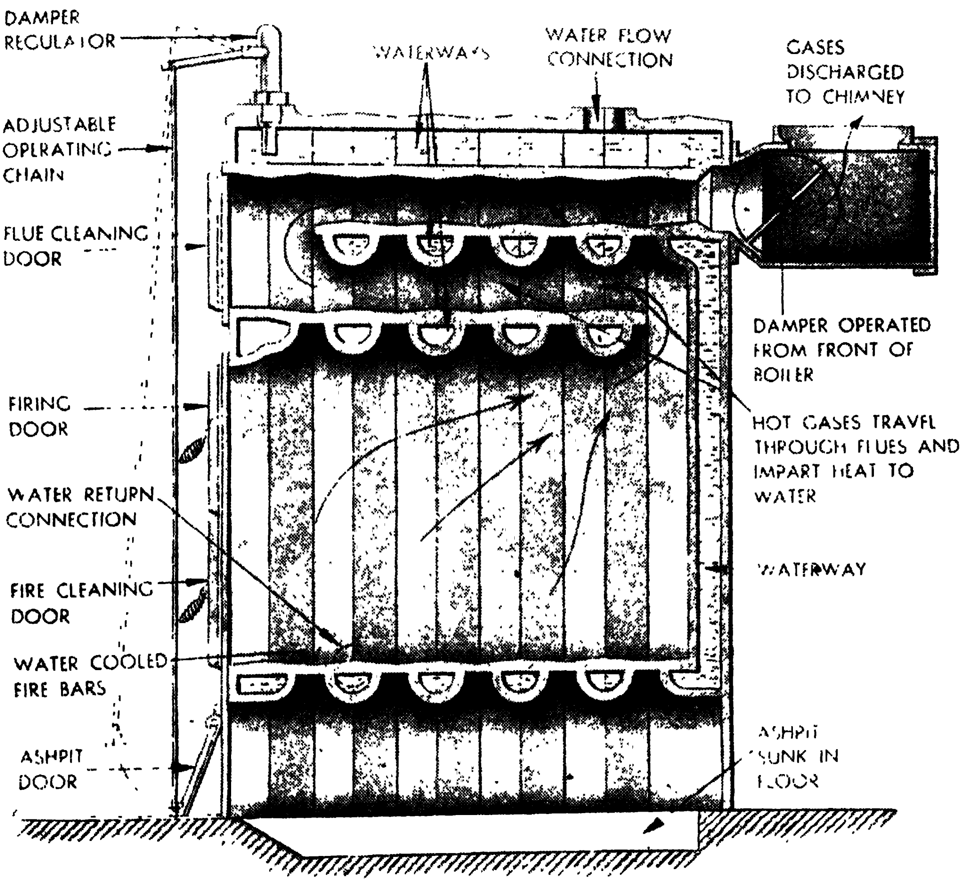
A type of self-contained gas water heater is the non-storage type, or geyser. This is only suitable for supplying a single point, such as a bath or sink, although one may be installed in a bath-

room between the bath and basin, with a swivel outlet which may be turned to discharge into the bath or basin, whichever is required (Fig. 6).

In this case there is no storage of hot water. When you turn on the water it passes through a coil of pipes upon which the gas jets impinge. The water is by this means heated from cold to a fairly high temperature instantaneously.

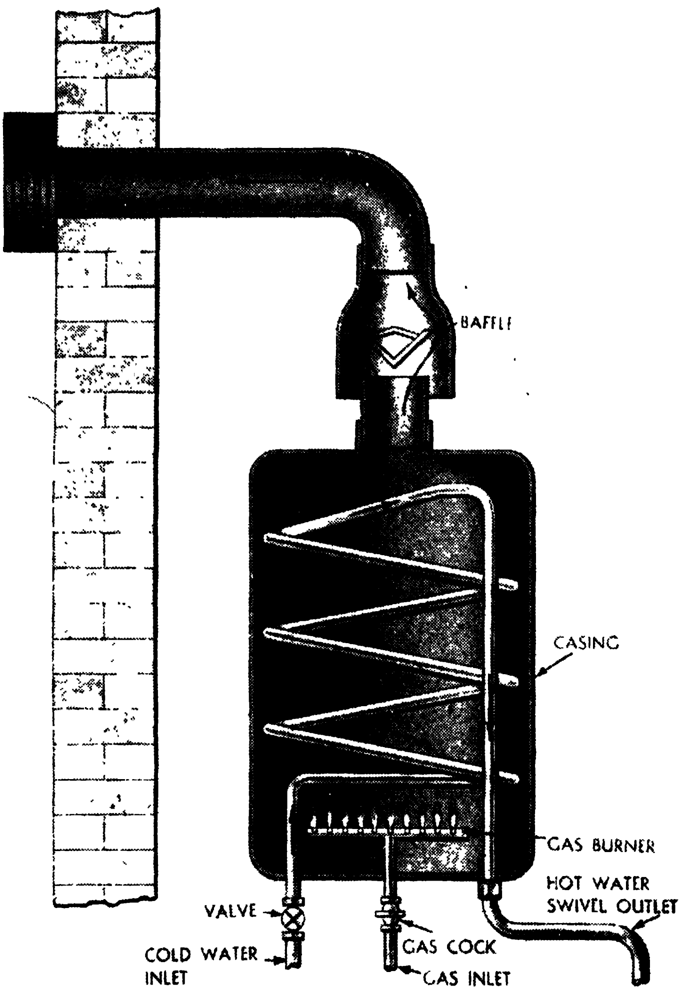
The rate at which hot water will flow through a geyser is limited by the fact that it must be heated on its passage, so that you cannot expect as rapid a flow as you get from an ordinary tap fed by some other means because time is needed in order to raise the temperature.

In the gas storage heater the gas burns all the time under the control of a thermostat, so that a supply of hot water is always maintained. The electric storage heater and the instantaneous heater are similar in all respects to the gas storage heater and geyser, except that the heating medium is now electricity (Fig. 7). In these cases, thermostatic



SECTION OF A LARGE TYPE OF BOILER

Fig. 5. With large boilers, one or both of the dampers can be controlled automatically so as to maintain a constant water temperature in the boiler without attention. This may be done by means of a lever connected to the damper, moved by a heat sensitive device immersed in the hot water. One type of regulator consists of a bulb containing automatic bellows, which compresses or expands according to the rise or fall of the temperature, and moves the damper accordingly



HOW A GEYSER WORKS

Fig. 6. The geyser is a self-contained, gas, water heater, only suitable for supplying a single point—bath or sink. When the water is turned on it passes through a coil of pipes on which the gas jets impinge. The water at once passes from cold to a fairly high temperature. The rate of flow, however, is limited because it must be heated on its passage

control is provided to ensure the economical operation of the system.

Where a hot-water system already exists, heated by an independent boiler, or from a back boiler, it is often advantageous to fit electric immersion heaters to the storage cylinder as well (Fig. 8). A similar arrangement can be made, using a gas in place of an electric heater. These can be used in the summer when it is not desirable to light a fire, or to boost up the temperature of the water when only a small fire is required. During the winter the system can work in the normal way, receiving its heat from coal or coke.

You now know how a hot-water system works, and how it should be installed. Perhaps you would like to examine your own system, and decide whether it is well designed, or whether it could be improved.

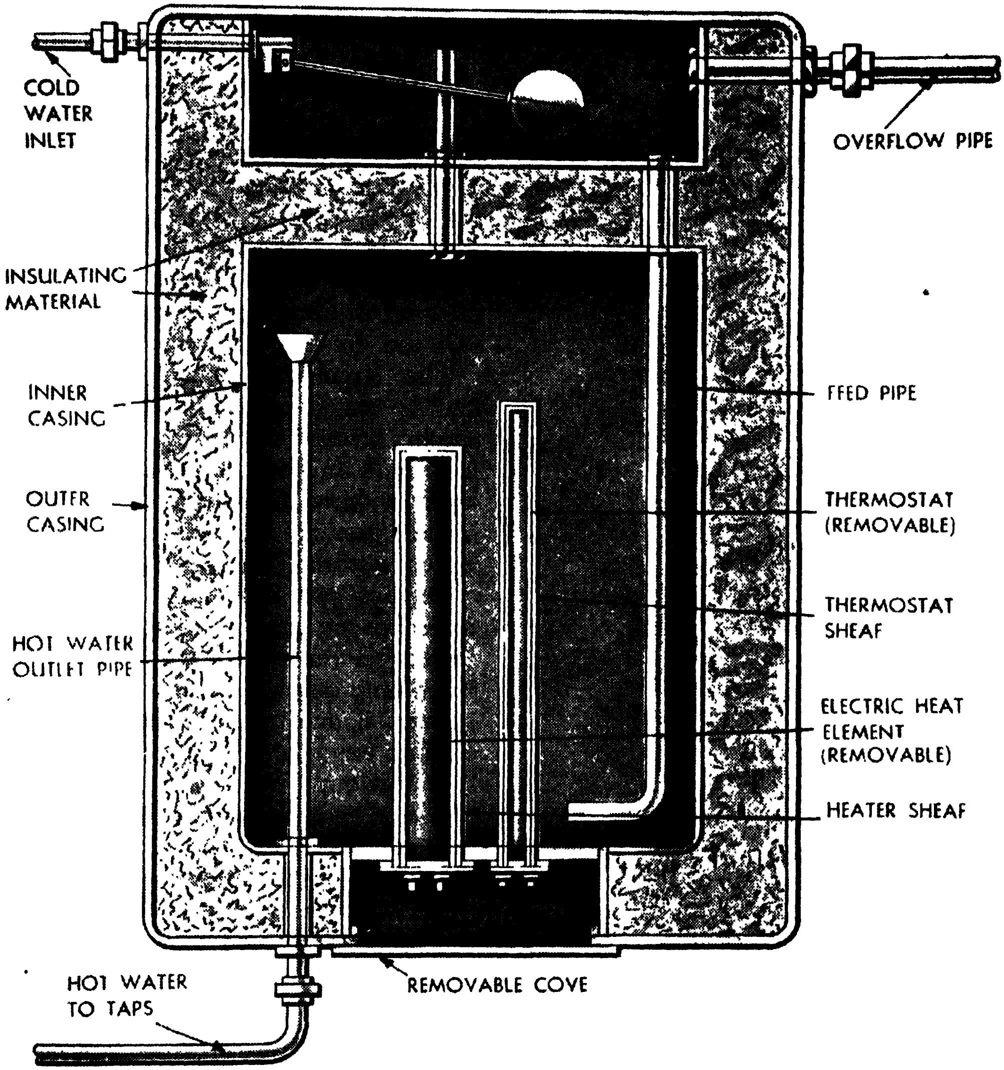
Firstly, does the general arrangement comply with the requirements which have already been outlined? If it does, there are still a number of points which may cause trouble.

Air can be troublesome if not properly dealt with. We have already seen that it gets into the pipes and rises and collects at the highest parts of the system.

All the pipes must, therefore, be fixed to rise towards one particular point, at which point we place our air pipe, so that all the air is cleared out of the pipes.

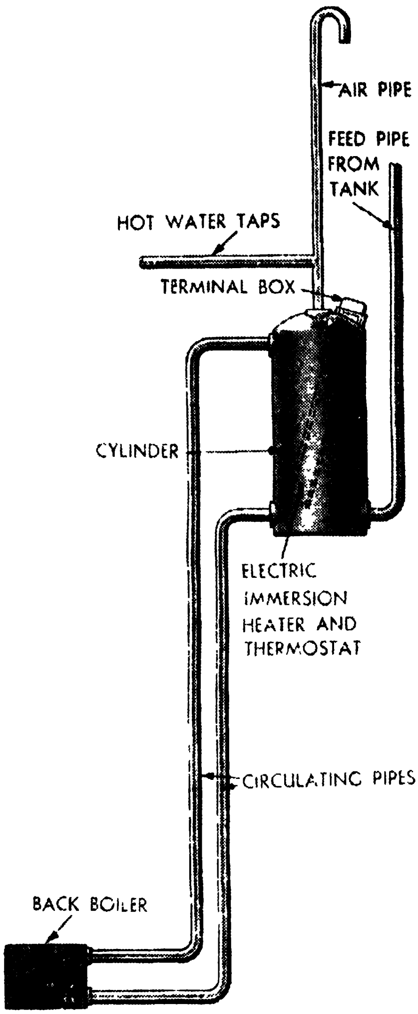
You should make sure that no pockets are formed in the pipe work in which air can collect. Although originally installed correctly, it may have been subsequently twisted or bent accidentally

such a way that it now forms an air pocket. If you have any lead pipes, they are particularly prone to deformation in this way owing to the softness of the metal. If lead piping has been laid in a roof, across the joists, it may sag in between these and form a point at which air will collect every foot or so. Actually



AN ELECTRIC STORAGE HEATER IN SECTION

Fig. 7. Though coke and coal are still the most universally used types of fuel, gas and electricity are also used and possess many advantages. Besides being clean and convenient, they are especially suitable for close automatic control. A storage heater, gas or electric, is a compact piece of apparatus embodying a heater and storage space, insulated and fitted in an enamelled sheet steel or similar casing. It may stand on the floor or be fixed direct to the wall above a sink or bath. The source of heat is constant, under control of a thermostat, so that the water is maintained at an even temperature. The thermostatic control keeps down the consumption of fuel and makes for the efficiency of the system, whilst maintaining an even heat. The essential parts are shown in this diagram



AN ELECTRIC IMMERSION HEATER

Fig. 8. When a hot-water system already exists, heated by an independent boiler or from a back boiler, it is often advantageous to fit an electric immersion heater to the storage cylinder as well. This auxiliary source of hot water is shown in the above illustration. It can be used in the summer when it is not desirable to light a fire, or to boost up the temperature of the water when only a small fire is required. During the winter the system can work in the normal way, then receiving its heat from coal or coke fuel.

all lead piping should be laid on boards and firmly fastened to them to prevent the pipes from getting out of shape.

The presence of air will produce bubbling noises in the pipes and intermittent flow of water from taps (it will probably come out in gushes). In more serious cases it may almost or completely fill a section of pipe at a high level and consequently break the water circuit, thus preventing the water from circulating round the system in the normal way.

DEFECTS OF CIRCULATION

If this happens in the boiler circuit it may result in the overheating and boiling of the water and perhaps even damage the boiler. If it happens in the circuit supplying the taps it will mean that as no water is circulating you will have to draw off all the water in the pipes before you can get any hot water.

The circulation round the system may be sluggish and unsatisfactory for another reason: that is that the pipes are too small. In this case, again, you may have to draw off a lot of tepid water before getting the really hot water which is stored in the cylinder.

Perhaps you find that when two or three taps are opened together the water discharges very much more slowly than when only one tap is open at a time, or perhaps if one tap is being used when another one near it is opened no water will flow out at all. Again, the pipes are not large enough, so that they are incapable of carrying all the water required. The fault in this case may lie in the pipes between cylinder and taps, or in the cold water pipe between the cold water tank and cylinder, or both.

A frequent source of trouble is the manner in which the storage pipes are connected with the storage cylinder. The two ends of the secondary circuit must both be connected near the top. The connexion of the feed pipe from the cold water tank to the cylinder is important. This should enter at low level but must be arranged so as not to discharge upward, otherwise cold water will shoot to the top and mix with the hot water.

WHAT HAPPENS WHEN YOU TELEPHONE

How the telephone transmits sound vibrations. What happens at the exchange. The automatic dial and its mechanism. The selector at work. Supplying the electric circuit. The distribution frame. Repeater stations. Radio-telephony. Radio-telephone circuits of today.

Each time we speak our voices set up vibrations which disturb the surrounding air—an effect which may be compared with that of ripples radiating over the surface of a pond after a stone has dropped into the water—and these vibrations travel through the air to be detected by our hearer's ear-drums.

Sound vibrations will travel through most materials: men have spoken to each other at a distance by the use of such devices as two thin sheets of wood, free to vibrate and connected at their centres by a mile or more of wire—the wire loosely suspended, from trees or poles, along its length. Sound vibrates the

HOW THOUSANDS OF WIRES ARE STORED AT AN AUTOMATIC EXCHANGE

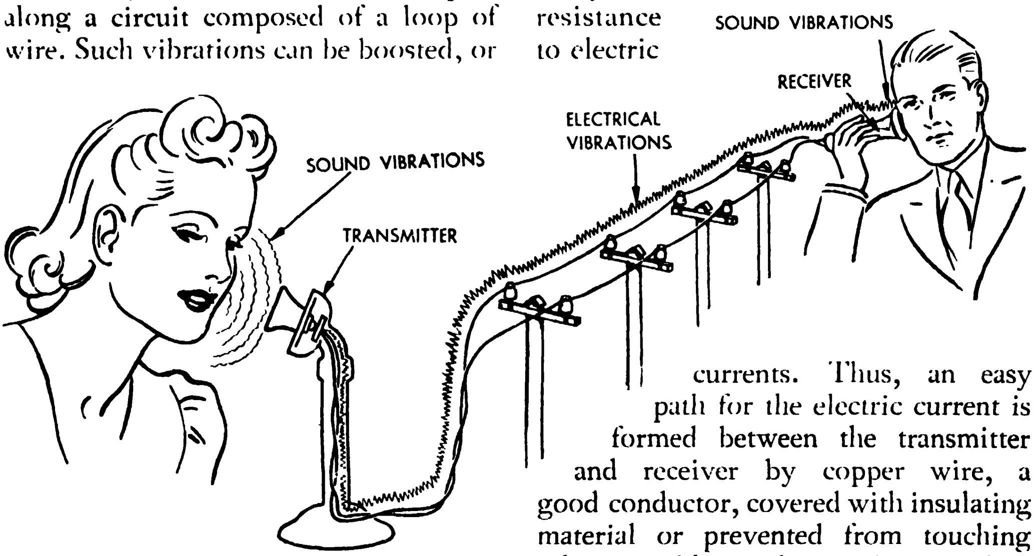
Every telephone has a pair of wires to itself, running to the common switching centre—the local telephone exchange. The arrangement of these wires, though it looks highly complicated, is perfectly systematic. This photograph was taken at an automatic exchange in London, controlling the lines of thousands of subscribers The lines, at the exchange, are brought into numerical order.

wood sheet which transmits these vibrations to the wire. These travel along the wire to set up similar vibrations in the distant wood sheet. Among the disadvantages of this system are the facts that the sound vibrations die down fairly quickly and do not travel particularly rapidly.

In the telephone system electrical vibrations, not sound vibrations, pass along a circuit composed of a loop of wire. Such vibrations can be boosted, or repeatered, to their original intensity should they fade. Their rate of travel is practically instantaneous for any length of circuit likely to be used in communication on this earth.

Now this is how the telephone works: the sound vibrations of the voice strike the drum, or diaphragm, of the telephone transmitter which translates them into electrical vibrations to flash along the line to the distant telephone receiver (Fig. 1). The diaphragm of the receiver responds to reproduce each detail of the transmitter's movements, to set air at the receiver into similar vibrations to those set up by the speaker's voice.

Some materials, conductors, allow electricity to flow through them fairly easily, while others, insulators, offer resistance to electric currents. Thus, an easy path for the electric current is formed between the transmitter and receiver by copper wire, a good conductor, covered with insulating material or prevented from touching other possible conductors by porcelain insulators such as those you have often noticed on the arms of telegraph poles.



HOW THE TELEPHONE WORKS

Fig. 1. The sound vibrations which are set up when we speak do not travel rapidly and die down rather quickly. Electrical vibrations, however, travel with instantaneous speed and can be kept at their original intensity. By means of the telephone, sound vibrations are translated into electrical vibrations. This translation takes effect by means of the drum, or diaphragm, of the transmitter from which the electrical vibrations flash over the wires to the distant telephone receiver. The diaphragm of the receiver sets up exactly similar vibrations to those which have been first caused by the voice of the speaker.

An electric current is made to flow in an insulated loop of wire, or circuit, and the telephone transmitter is placed in this circuit. The transmitter has to be made of a material which will allow current to flow through it but will vary the amount of current passing in close response to the varying sound vibrations striking its diaphragm. To achieve this the copper wire is connected to the diaphragm through which the current travels into a small cup almost filled with little grains of black carbon, then through this carbon into the copper wire again (Fig. 2). The lid of the cup is fixed to the centre of the diaphragm and is able to move inside the cup. Thus, as the diaphragm bends inwards it compresses the grains of carbon more closely

"YOU'RE THROUGH"—TELEPHONE OPERATORS AT THE SWITCHBOARD

The telephone exchange provides the means of speaking to a choice of telephone users. Each user's pair of wires is connected to a switchboard. When you lift your telephone from its rest your line circuit is automatically closed to enable an electric current to flow through it and a lamp denoting your line glows on the switchboard. The telephone operator seated there switches her telephone on to your circuit and having ascertained the number of the telephone user to whom you wish to speak she connects your line to his. To do this she fits a plug into a brass-lined hole in the switchboard, associated with the particular line in question. Figs. 3 and 3a show details of the apparatus

FITTING A ROBOT SWITCH AT THE AUTOMATIC EXCHANGE

This photograph is in striking contrast with that shown on the previous page. A piece of mechanism takes the place of the telephone operator at the exchange. Aided by an electric lamp fitted to his head a Post Office engineer adjusts the delicate switches which dispense with manual operation.

together and immediately more current is able to flow through them. The greater the movement the more tightly the carbon is compressed and the larger the current that flows.

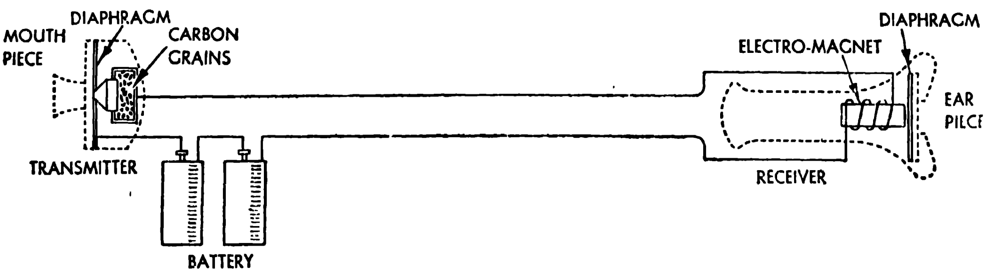
To understand what happens at the telephone receiver we must have some idea of the principles of an electro-magnet. When an electric current flows through a helical coil of insulated wire a magnetic effect is set up in the coil. If the coil is freely suspended it will behave like the needle of a magnetic compass, that is, it will swing around till one end is pointing to the North. It will also tend to attract iron. Form the coil around a bundle of soft iron wire and this magnetic effect is enormously increased. The magnetic effect will persist as long as an electric current is flowing through the coil. The magnetism will vary in intensity with the amount of current flowing, the greater the current the greater the magnetic effect.

DIAPHRAGM AND ELECTRO-MAGNET

Knowing this, for the telephone receiver we join each end of the wire of the telephone circuit to each end of the winding of an electro-magnet. Now if we put an iron diaphragm close to one end of the electro-magnet the diaphragm will be pulled towards it when a current flows in the coil winding. The diaphragm used in the receiver is a thin iron disc clamped around its edge and sufficiently flexible for its centre to be able to move a certain amount. The greater the current flowing in the coil the nearer the diaphragm moves towards the electro-magnet. The resulting vibrations of the diaphragm disturb the air between it and your ear in unison with the disturbed air at the transmitter: thus you hear what seems to be the voice of the distant speaker. It only remains to place a transmitter and a receiver at each end.

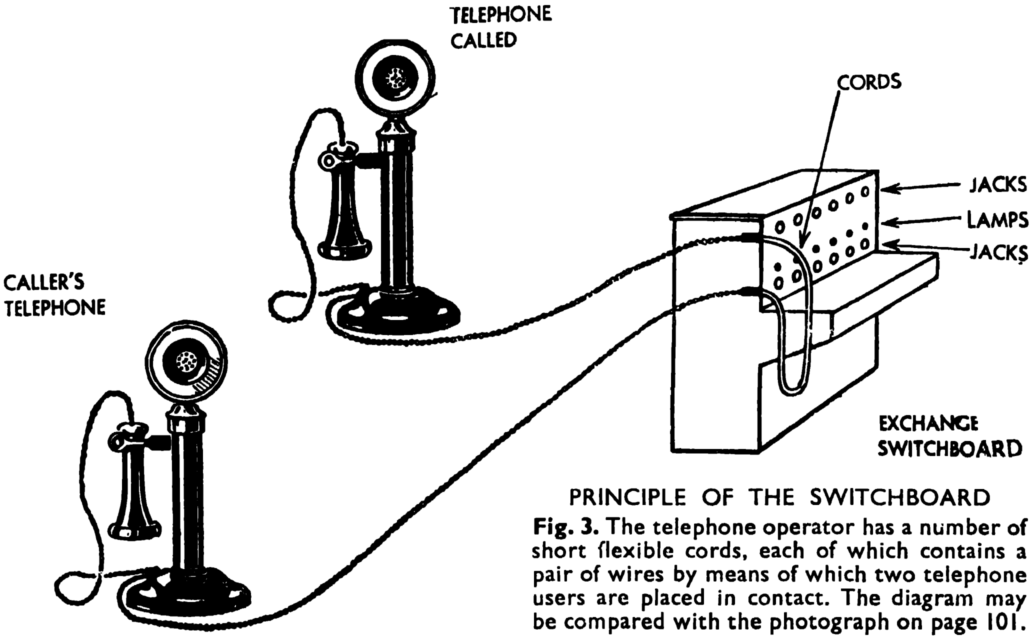
AT THE TELEPHONE EXCHANGE

If you want a choice of telephone users to whom to speak then a central switching point, a telephone exchange, has to be provided. Here each user's pair of wires is connected to a switchboard. When you lift your telephone from its rest your line circuit is automatically closed to enable an electric current to flow through it—from a central power supply at the exchange—and a tiny lamp associated with your line glows on the switchboard (Fig. 3). The telephone operator seated there switches her telephone on to your circuit and having ascertained the number of the telephone user to whom you wish to speak she connects your line to his. To enable her to do this she has a number



A SIMPLIFIED TELEPHONE CIRCUIT

Fig. 2. Electrical vibrations pass along a circuit composed of copper wire. The telephone transmitter is placed in this circuit and the wire is connected to the diaphragm through which the current travels into a cup filled with grains of carbon. The lid of the cup is fixed to the centre of the diaphragm, moving correspondingly. The current increases as the carbon is compressed, the diaphragm in the receiver moving towards an electro-magnet in accordance with the strength of the current. The resulting vibrations of the diaphragm reproduce those already created at the transmitting end



PRINCIPLE OF THE SWITCHBOARD

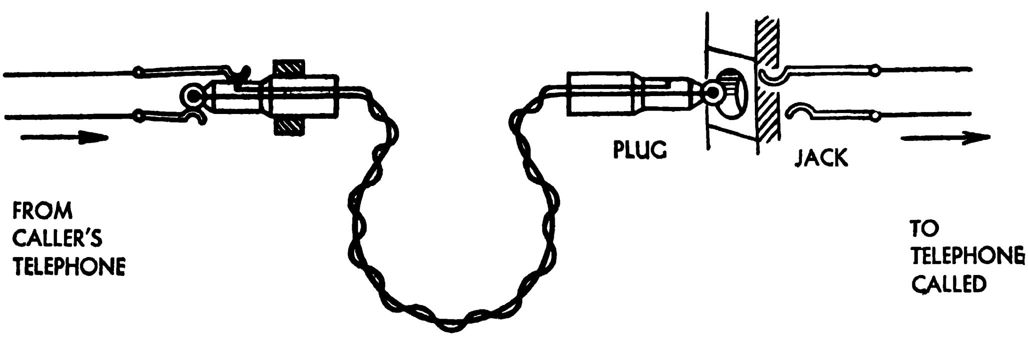
Fig. 3. The telephone operator has a number of short flexible cords, each of which contains a pair of wires by means of which two telephone users are placed in contact. The diagram may be compared with the photograph on page 101.

of short flexible cords at her position: each of these contains a pair of wires and is fitted with a plug at each end. The plug fits into a jack, a brass-lined hole in the switchboard, to which your circuit is brought. A jack is associated with each line led into the exchange so that by the use of one of her cords any two circuits can be connected (Fig. 3a).

THE AUTOMATIC SYSTEM

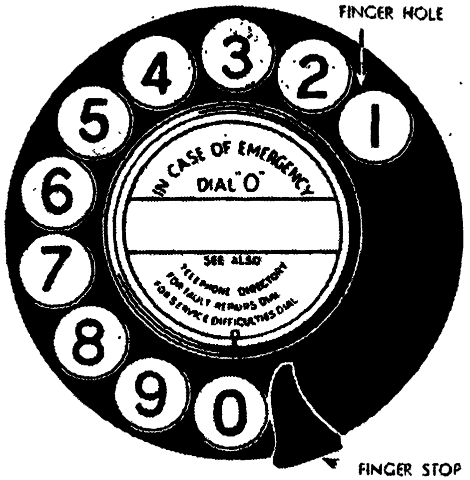
The automatic telephone system enables you to get any of the numbers at an exchange, at all hours of the day and night, without calling upon a telephone operator at the exchange. It was first introduced into this country at Epsom, Surrey, by the Post Office in 1912. This experiment was so successful that gradually other manual exchanges were replaced by automatic exchanges so that today more than half the three million telephone subscribers in the United Kingdom have automatic telephones.

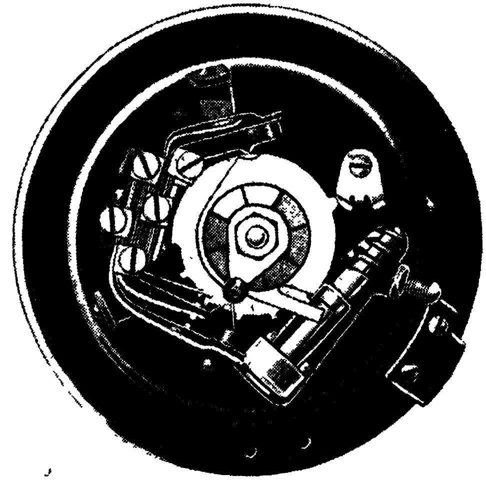
Each telephone is fitted with an automatic dial (Fig. 4). This is circular and

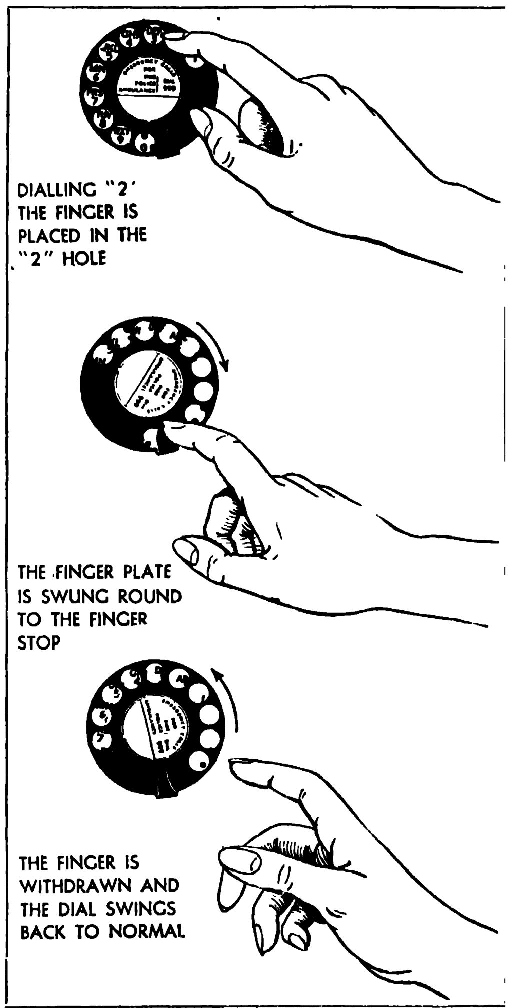


HOW TWO CIRCUITS ARE BROUGHT TOGETHER

Fig. 3a. The cords used by the operator are fitted with a plug at each end and the plug fits into a brass-lined hole in the switchboard called a jack. A jack is associated with each line led into the exchange so that by using one of her cords the operator can connect any two circuits, as may be seen from the above diagram. Fig. 3 shows the position of jacks and the lamps which signal a call.







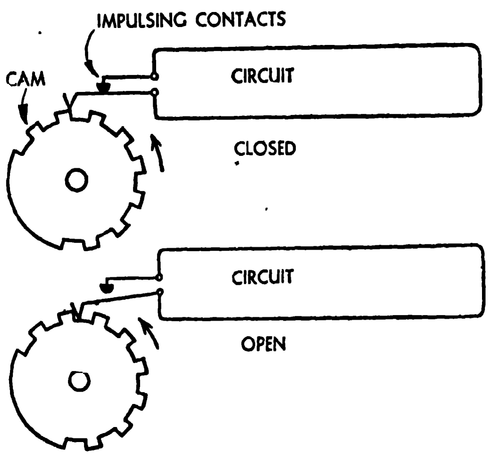
HOW THE DIAL OF AN AUTOMATIC TELEPHONE WORKS

Figs. 4, 4a and 5. Most of us are familiar with the dial attached to the telephone by means of which we can put ourselves into direct contact with some other telephone user. Most of us also have manipulated it ourselves as shown in Fig. 5 (above, right). We may not, however, have given thought to the ingenious mechanism which is concealed behind the finger plate. When you have withdrawn your finger after swinging the plate round to the stop, a train of interruptions is produced in the electric current which flows in the line circuit when the telephone is taken off its rest. The number of interruptions corresponds with the figure dialled—that is to say, if "2" is dialled the current is interrupted twice, if "7" the current is interrupted seven times and so on. When "0" has been dialled ten interruptions are made. These interruptions operate electro-magnets which control switching apparatus at the exchange. The dial mechanism is operated by the rotation of the spindle on which the finger plate is fixed and a spring returns the plate to its normal position when it has been released. The mechanism includes a governor which serves to control the speed of the dial.

has a finger plate on its front with ten holes stamped in it through which can be seen the numbers 1 to 9 and 0. You place your index finger in one of the holes and swing the finger plate around in a clock-wise direction until the movement is brought to an end by the finger stop (Fig. 5). You then withdraw your finger and the plate revolves back to its former position. On its return journey

it produces a train of interruptions in the electric current which flows in the line circuit when the telephone is taken off its rest. The number of interruptions corresponds to the figure dialled; that is to say, if "2" is dialled the current is interrupted twice, if "7" the current is interrupted seven times. When "0" has been dialled ten interruptions are made. These interruptions operate electro-magnets that control switching apparatus installed at the exchange itself.

A more detailed description of the dial operation can be followed with the aid of the illustrations. Mechanism in the dial case is operated by the rotation of the spindle on which the finger plate is fixed (Fig. 4a). A spring returns the plate to its normal position when it has been released. During its return, contacts controlled by a cam wheel interrupt the current flowing in the circuit the number of times that corresponds with the hole selected (Fig. 6). This series of interruptions is known as an impulse train. The impulses are sent out on the return rotation of the dial so that their train is not disturbed or distorted by any hesitancy on the part of the person dialling. The mechanism includes a governor, similar to that on a gramophone, to control the speed of the dial.



HOW THE DIAL SENDS OUT IMPULSES

Fig. 6. As the plate returns to normal, contacts controlled by a cam wheel interrupt the current flowing in the circuit the number of times corresponding with the hole selected. This series of interruptions is known as an impulse train and is sent out on the return journey so that it is in no way disturbed by the person who is dialling.

THE SELECTOR MECHANISM

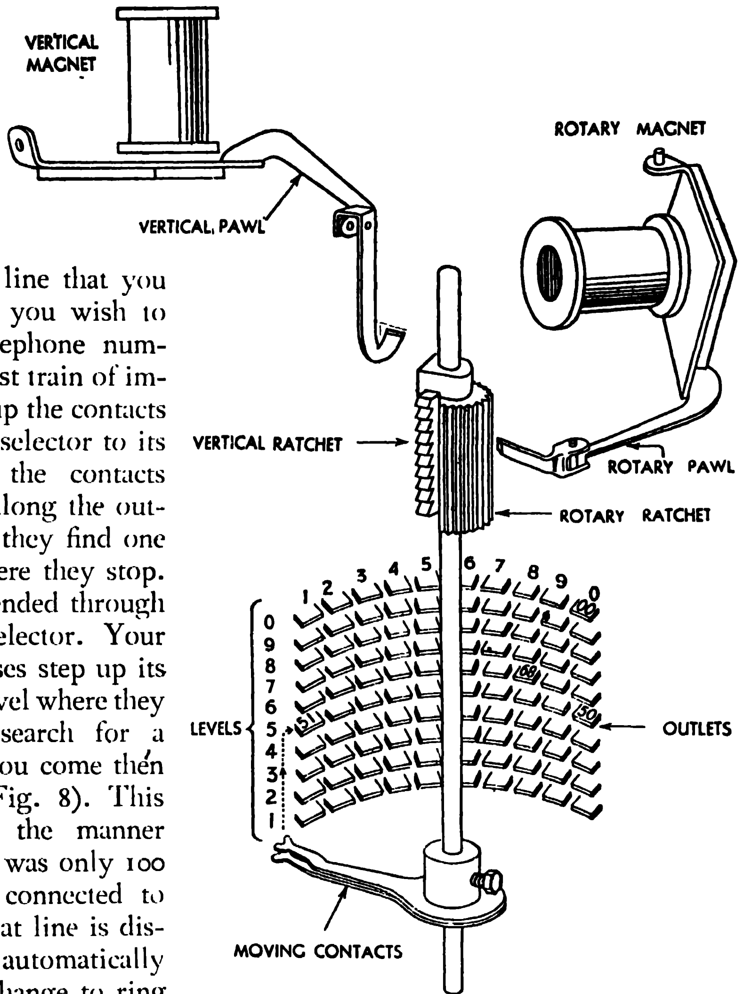
A piece of mechanism takes the place of the telephone operator at the exchange. Arranged in an arc at the base of this selector mechanism are 100 outlets to each of which an insulated wire is soldered. As an impulse arrives at the selector it energizes a vertical electro-magnet which attracts a flat plate of iron, fitted close to it and hinged at one end. To this is attached a metal finger, the vertical pawl which engages in a notch of a vertical ratchet to lift the moving contacts of the selector on to the first level of outlets. The pawl disengages the ratchet as each impulse ceases, at which moment the electro-magnet has ceased to exercise any magnetic attraction. Each succeeding impulse in the train repeats this operation and the contacts are thus lifted a step at a time till the train is completed. The next train of impulses operate a rotary electro-magnet in a like manner. Here a rotary ratchet is engaged to pull the contacts around a step at a time on the level to which the vertical pawl has raised them (Fig. 7).

From this description it will be seen that if 100 lines are connected to the 100 outlets of the selector then any one of these can be selected to connect to your telephone by the procedure of dialling two trains of impulses.

If the number of the telephone user to whom you wish to speak is "45" then you first dial "4" and the moving contacts of the selector obediently step up to the fourth level of the banks of outlets. You next dial "5" and the contacts move along this level till they stop at the fifth outlet on this level. Thus

your own telephone line is connected to that numbered "45."

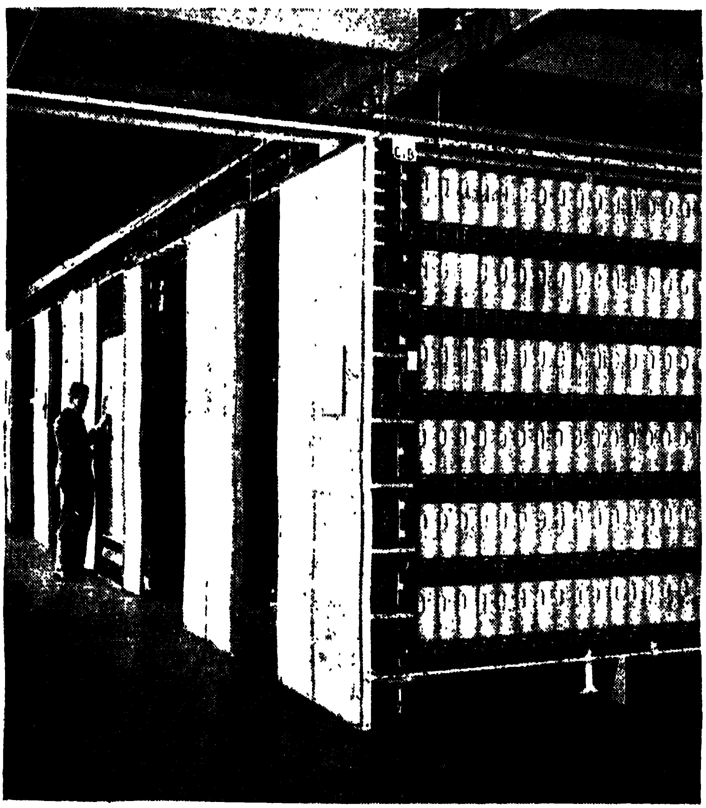
Suppose, however, that there are 10,000 users connected to an exchange. More switches will be necessary to find the line that you require. Assume that you wish to connect with the telephone numbered "2345." The first train of impulses you dial steps up the contacts of a thousands group selector to its second level. Now the contacts automatically sweep along the outlets on that level till they find one that is not in use where they stop. Your line is then extended through a hundreds group selector. Your second train of impulses step up its contacts to the third level where they make an automatic search for a disengaged outlet. You come then to a final selector (Fig. 8). This selector operates in the manner described when there was only 100 lines. You are thus connected to number "2345"; if that line is disengaged current is automatically sent out from the exchange to ring the wanted user's telephone bell.

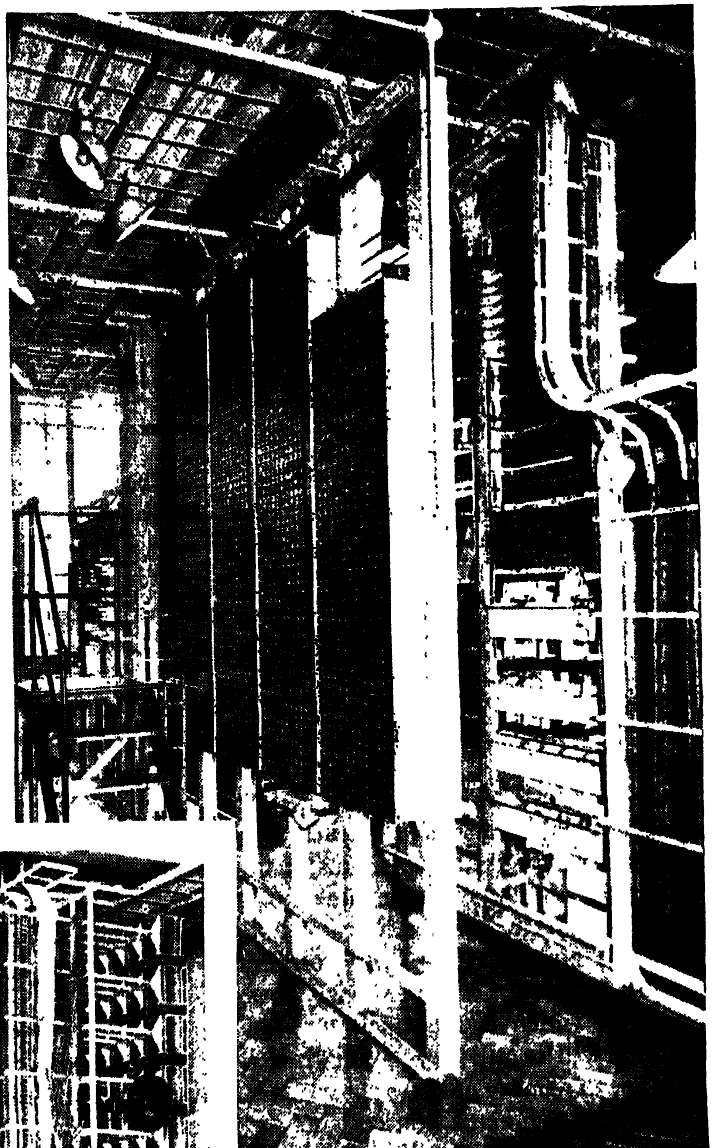


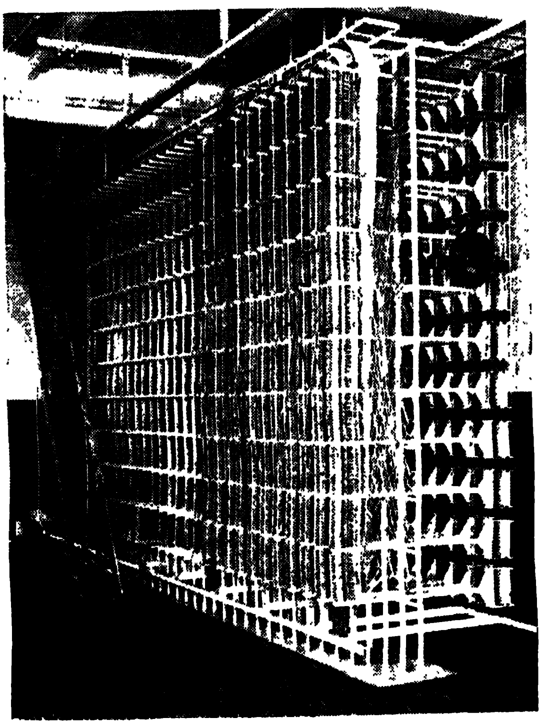
THE PRINCIPLE OF THE SELECTOR

Fig. 7. This mechanism takes the place of the manual operator. The trains of impulses energize first, a vertical magnet; second, a rotary magnet These operate mechanical fingers, the vertical and rotary pawls which move the contacts up, in one case, across in the other, to the outlets corresponding to the number dialled. The lines are connected to each of the outlets and it is through them that the connexion is made

There is an important difference between supplying electricity to light lamps and heat electric cookers and supplying an electric circuit for your telephone. The first comes from a main supply something after the manner of water or gas. A telephone, however, cannot be tapped into a common supply. Your telephone has a pair of wires all to itself which have to run to the common switching centre—the local telephone exchange. Here your pair of wires will be found in a lead-covered cable with probably hundreds of others—each carefully insulated from the remainder. These lead-covered cables, which have reached the exchange along different streets, are led into an underground chamber. From here they pass up through the roof of the chamber to a cross-connecting position in the room above. The cables are connected to one side of an iron framework in the order in which they enter the building. By the use of cross-connecting wires the line

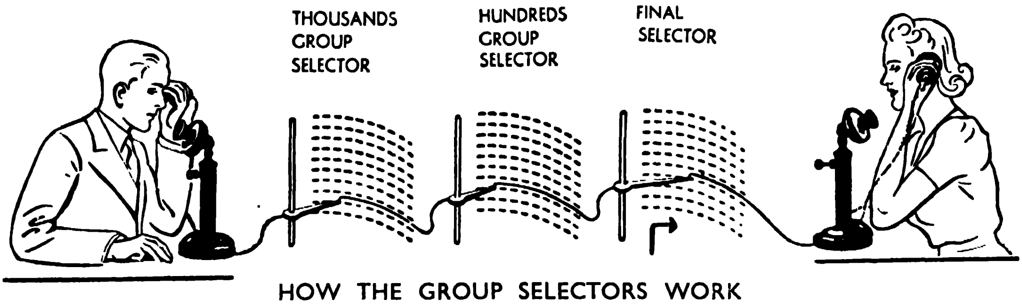






APPARATUS OF A TELEPHONE EXCHANGE

The pair of wires which is the personal and private accessory of your telephone runs with hundreds of others in lead-covered cables—each carefully insulated from the rest. The photograph, above left, shows the cable chamber at an exchange. The cables are connected to one side of an iron frame work in the order in which they enter the building. By cross connecting wires the lines are brought into numerical order on the exchange side of the main distribution frame which is shown in the centre illustration. Each telephone subscriber has a separate meter connected to his line and the meter racks are shown above. At left, on the opposite page, are the orderly racks of selectors.



HOW THE GROUP SELECTORS WORK

Fig. 8. If there are, say, 10,000 users connected to one exchange a number of switches are necessary to find the required line. The first figure dialled operates a thousands group selector, the second extends your line to a hundreds group selector. You are then through to a final selector which finds the remaining two digits of your four-figure number as has been illustrated in Fig. 7. If the line is disengaged, current will then be automatically sent from the exchange to ring the user's bell.

are brought into numerical order on the exchange side of the frame, thus making it easy to test and maintain any line.

THE DISTRIBUTION FRAME

Each line is also fully protected on the main distribution frame as this cross-connecting frame is known. The telephone at your house is fully protected against lightning discharges and stray electric currents which might be picked up from outside sources in unusual conditions; so also is the apparatus at the exchange protected from the same possibility of damage. These devices include a fuse (a normal safety fitting on any electrical circuit): a current may flow, however, which is too small to blow the fuse, but is still large enough, if it persists, to damage delicate apparatus in the exchange and so a heat coil is fitted which will disconnect the line should the fuse have failed to operate. In addition there is a carbon protector through which lightning discharges, which would jump across the fuse, will flow harmlessly into the ground instead of into the exchange apparatus.

Each telephone subscriber has a separate meter connected to his line. The meter works on the same principle as a cyclometer, and is operated only when the subscriber you have been calling actually answers your call.

The electrical power necessary to operate the exchange and supply current to the subscribers' telephone lines is provided by the battery room of the exchange. Here are large storage batteries, weighing in some exchanges over sixty tons. They are regularly charged from motor generators, in the power room of the exchange, driven from the public supply mains. Here other machines generate the special currents for ringing the bells and producing the various signal tones. To ensure that a breakdown will not interrupt the service, the duplication of both batteries and generators is provided for.

SELECTOR RACKS

The selectors are mounted on racks in the apparatus rooms. It would cost far too much for each subscriber to have a complete set of the very expensive automatic switches waiting idly at the exchange for his occasional call. Nor is this necessary since all the subscribers will not be making calls at the same time and so only enough switches are fitted to meet the needs of the particular exchange at its busiest hour of the day.

The number of exchanges in the telephone area of a town is usually so small that it can be arranged for selectors to find a route to any exchange in the area at the same time as they are selecting the

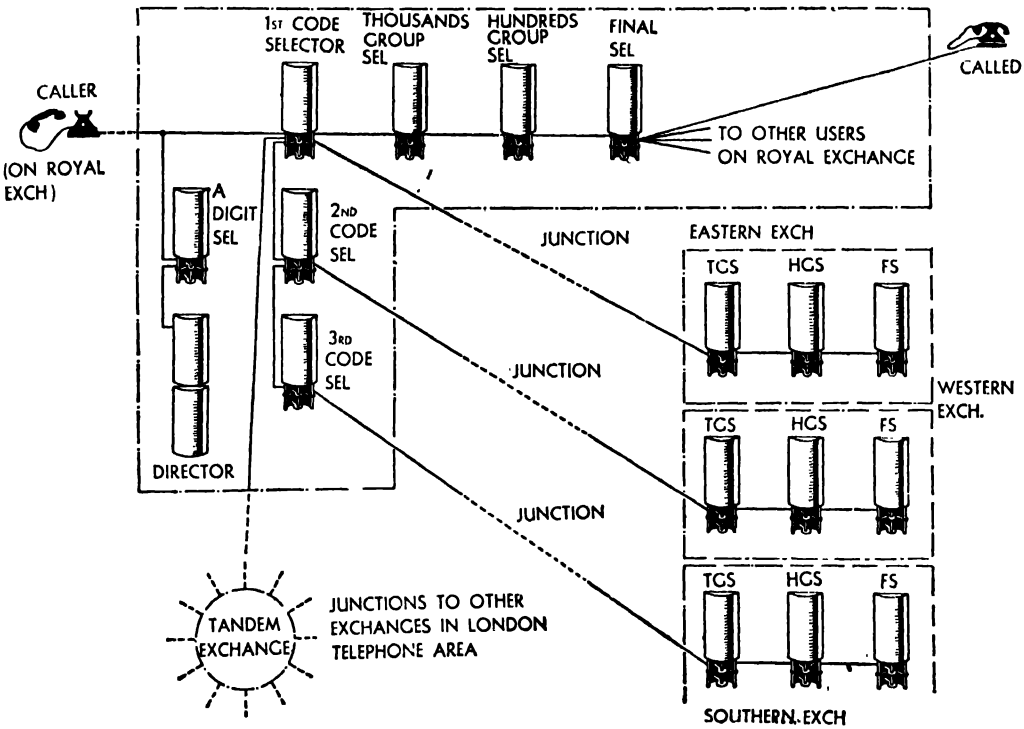
required number. In very large areas, such as London (which has over 100 exchanges), a special piece of apparatus —a switch known as a director—is used to find a route to the required exchange.

CALLING AN EXCHANGE

Four-figure numbers are still used, but these are preceded by the first three letters in the name of the called exchange. By this means you do not have to remember a long series of numbers. These letters appear in groups above the numbers which appear on the telephone dial.

When you lift your telephone you are connected to an A digit selector switch at your local exchange (Fig. 9). The train of impulses sent out by dialling the first letter causes the moving contacts of the A digit selector to step up to the level signalled where its contacts automatically rotate to search for a free outlet to one of a group of ten directors wired to that level. The director may be likened to a mechanical operator which takes charge of the call and routes it to the required exchange. Under the guidance of the second and third letters dialled the director finds a junction line through to the required exchange.

While this is being found the director absorbs and stores up the four trains of numerical impulses you have dialled. It translates the second and third letter



HOW YOU FIND THE EXCHANGE YOU WANT

Fig. 9. When you lift your telephone you are connected to an A digit selector switch at your local exchange. The train of impulses sent out by dialling the first letter causes the contacts to search for a free outlet to one of a group of directors. Under the guidance of the second and third letters the director finds a line to the exchange. It stores up the trains of numerical impulses, translates them according to the exchange required and sends them out to operate code selectors. If there is no direct junction line to the exchange dialled, these code selectors find an outlet to a main switching centre or tandem exchange. Tandem selectors operate until the junction line is picked up. The director then sends out numerical impulses to operate the group selectors of that exchange

impulses into from one to six trains, the number of trains and the number of impulses in each train depending on the exchange required. These it then sends out to operate a code selector whose contacts step up to the level signalled by the director and search for a free outlet. If this outlet is connected direct to a nearby exchange the route has been found and the director can transmit the four numbers it has stored. In this instance the director has translated the second and third letter impulses into a single train of impulses.

THE CODE SELECTOR

When it sends out more than one train of translated impulses additional code selectors are operated. If there is no direct junction line to the exchange dialled, these code selectors find an outlet to a main switching centre, a tandem exchange. Subsequent translated impulses operate tandem selectors till a junction line is picked up; the director then sends out the numerical impulses to operate the thousands, hundreds, and final group selectors of that exchange. As soon as this chain of connexions is completed the A digit selector and the director are released from the circuit to become free for use by another caller.

As telephone currents pass along a line they decrease in strength and on a very long line they become too weak to actuate the distant receiver. Special repeater stations are therefore built through which are led the underground cables carrying the telephone lines. At these the speech currents are magnified to their original intensity by means of repeater apparatus, which include thermionic valves similar to those used in ordinary radio receiving sets. These stations are placed on the cable routes.

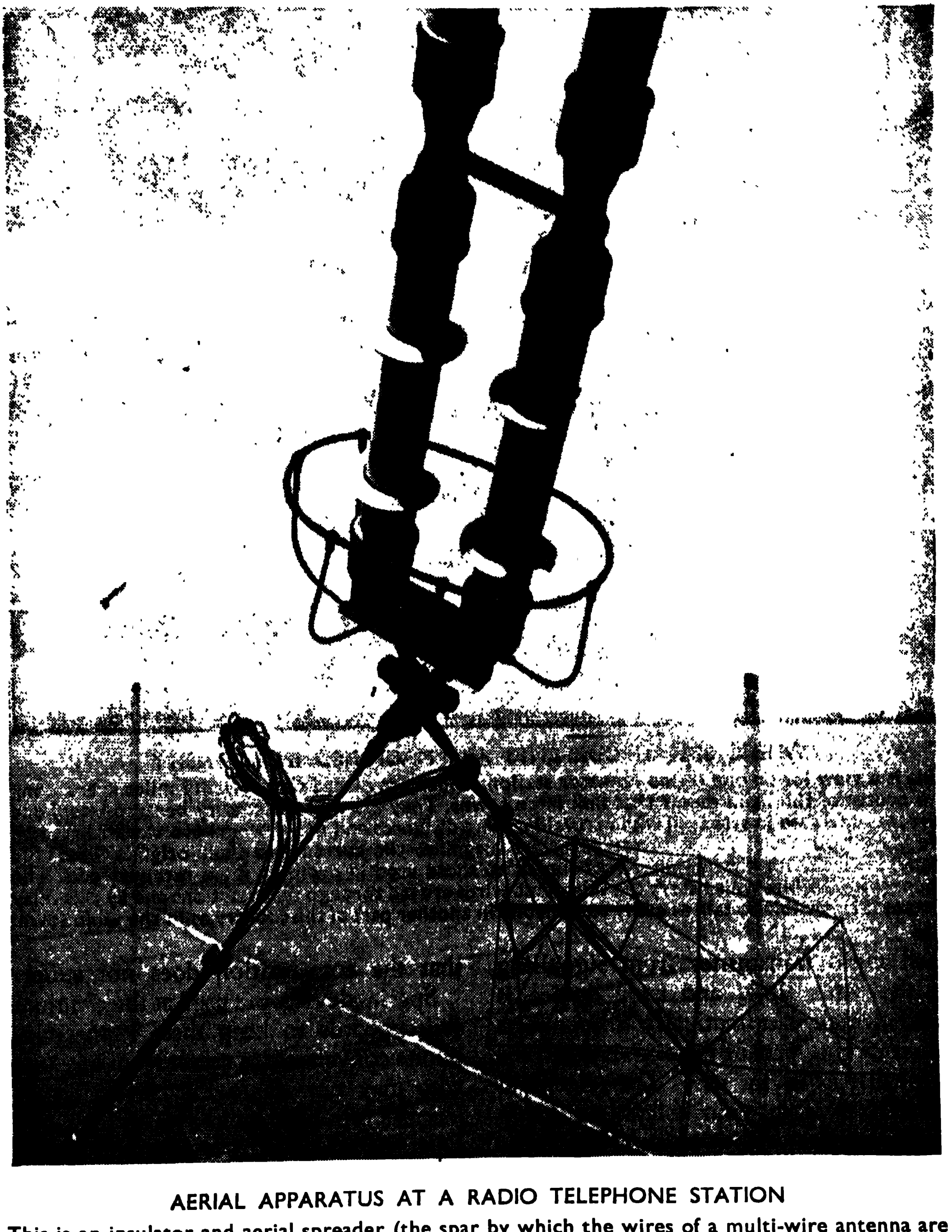
Radio telephony, which has been made possible by the development of the thermionic or wireless valve, is based on much the same principles as ordinary line telephony. Sound vibrations are converted into electrical vibrations by means of a transmitter, or microphone, and the ordinary telephone transmitter is quite suitable for this purpose. The vibrations radiated through space from radio stations are of much higher frequencies than those flowing from the microphone. They are therefore tuned to send out a carrier wave of a fixed high frequency and the varying lower frequencies from the telephone transmitter are allowed to mix with this or, as it is called, to modulate the carrier wave. At the radio receiver the resultant radio-frequency vibrations are split into their two component parts. One of these is the unwanted carrier. Since the other is the vibrations set up by the telephone transmitter it is readily detected by a telephone receiver.

The post office radio station at Rugby, one of the largest in the world, enables you to speak to practically any one of the telephone users throughout the world. In such ships as the *Queen Mary* there is a telephone in each cabin, and by means of radio telephony it would be possible for you to speak to a friend in one of these cabins even while the ship was in mid-Atlantic.

RADIO TELEPHONE CIRCUITS

The first public radio telephone circuit of the post office was opened to the United States of America as long ago as January, 1927. Today there are quite a number of such circuits between these two great English-speaking countries. The circuits are controlled in each country at radio telephony terminal switchboards by engineers who maintain the efficiency of the complicated circuits. Separate radio stations are used for transmitting and receiving.

When there is a radio link in a telephone circuit it is necessary to prevent



AERIAL APPARATUS AT A RADIO TELEPHONE STATION

This is an insulator and aerial spreader (the spar by which the wires of a multi-wire antenna are spaced apart from each other) at the post office radio station at Rugby, one of the largest in the world. A station of this kind enables you to speak to practically any of the telephone users throughout the world—on ships at sea as well as on land. This wonderful achievement was made possible by the development of the thermionic or wireless valve, though in principle radio telephony is much the same as ordinary line telephony. Sound vibrations are converted into electrical vibrations by means of a transmitter or microphone and the ordinary telephone transmitter is quite suitable for this purpose. The vibrations radiated through space from radio stations are tuned to send out a carrier wave of fixed high frequency and the varying frequencies from the telephone transmitter mix with or modulate this wave, being quite easily separated from it at the receiving station.

WHERE SPEECH CURRENTS ARE MAGNIFIED IN INTENSITY

This is a view inside one of the repeater stations which are placed some twenty miles apart along the routes of the main cables that link large towns. They are made necessary because telephone currents decrease in strength when travelling long distances and may become too weak to actuate the distant receiver. The repeater apparatus magnifies the currents to their original force, the apparatus including thermionic valves similar to those used in ordinary radio receiving sets. The underground cables which carry the telephone wires are led through these stations and by this relay system it is possible to talk as easily to someone in another part of the country as in the same town.

each radio transmitter from signalling at the same time, and so a device is used which automatically disconnects the receiving part of the circuit when the transmitter is in use. The electrical vibrations from your telephone transmitter actuate sensitive switching apparatus to put your receiving path out of action when you speak. The moment you stop speaking and your American friend begins to reply your receiving path is immediately in operation and your sending path disconnected. Thus the receiving and sending paths are constantly switched in and out of the circuit but this is done so rapidly and silently that the conversation does not suffer.

Special devices are used at the terminal switchboards to keep these radio telephone conversations secret from any one who may tune in to the carrier wavelength on his radio receiving set. Distorting apparatus is introduced into the circuit so that any signals picked up by an ordinary radio receiver are merely an unintelligible jumble of sounds. At the receiving terminal this scrambled speech is reconverted to the form in which it was transmitted from your telephone, and is sent along a trunk line to your friend's local exchange and thence to his telephone.

HOW YOUR CLOCK TELLS THE TIME

The motive power of a clock. The essential parts of a clock. The striking clock and its mechanism. The chiming clock and how it chimes. The weight-driven clock and how it works. The alarm clock and how it operates. The synchronous electric motor clock.

THE prime object of the clock, to tell or indicate the time of day, is achieved by the control or regulation of motive power. A system of gearing transmits the power which keeps the regulator or governor, as it is called, functioning. There are various forms of governors—the pendulum, the balance and the rotor (used in mains electric clocks). The motive power can, generally speaking, be divided into three categories: (1) spring-driven, (2) weight-driven and (3) electrically-driven. Each of these systems is here described, and it will be seen that any machine which can be made to function regularly will serve as a clock.

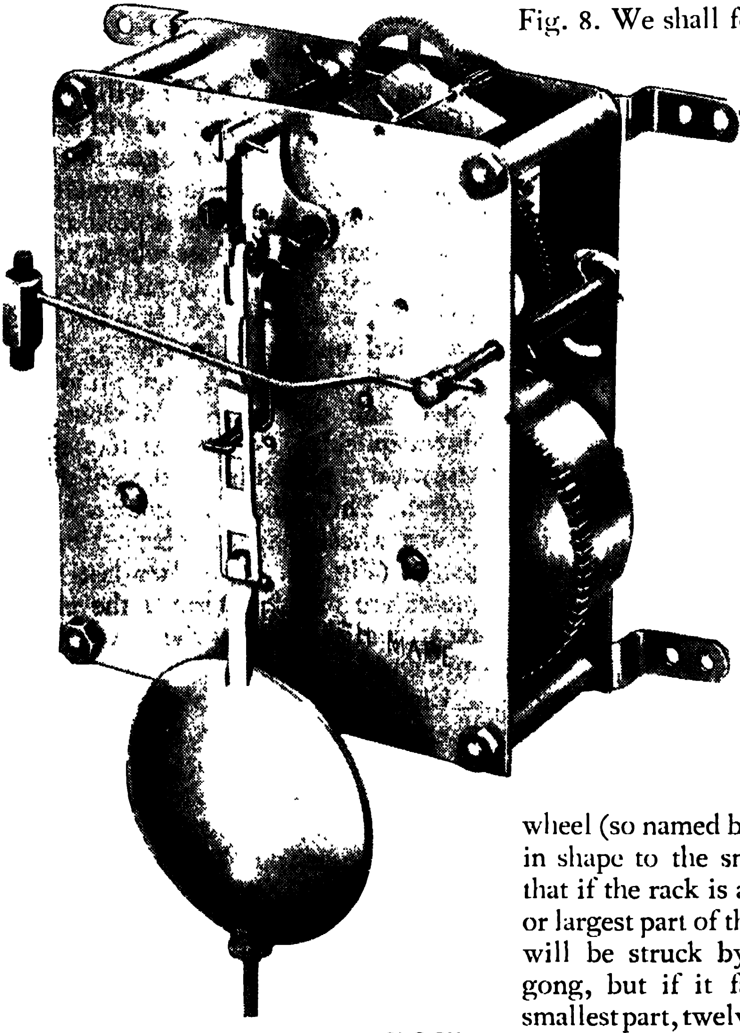
A STRIKING CLOCK

Here is the mechanism from the back of a striking clock (Fig. 1). A strip of hardened and tempered steel is the motive power. We all know that, if a piece of spring steel is bent it will return to its original shape providing it is not bent at too acute an angle—and it is this property which is employed to make this clock work. A strip of steel is coiled into the round box or barrel, usually made of brass (Fig. 2), and, in turn, this spring is wound round a steel piece, the barrel arbor (Fig. 3). It is obvious that if the arbor, after winding up the spring on to it, is held securely, and the other end of the main spring is secured to the side of the barrel, the barrel will revolve (Fig. 4). The barrel, as you will see, has attached to it teeth, or a geared wheel, and this wheel gears into a small steel wheel or cog, known as a pinion. This pinion gears into a brass wheel, and the brass wheel again into a steel pinion, and so on. If, when the barrel is in the clock, we wind up the main spring, it will cause all the wheels and pinions to rotate and the mechanism would run down quickly. To prevent this an obstruction is placed in the path of the last wheel. This wheel is known as the escape wheel, and the obstruction, the pallets (Fig. 5). These two last-named pieces are together termed the escapement, and they allow the power of the mainspring to escape.

Clockmakers have so arranged it that the power escapes at a regular speed, and so we have timekeepers. Examine Fig. 5 carefully. The wheel is made to revolve as indicated by the arrow. The tooth A wants to pass, but before so doing it must push the pallet B out of its way. Now, connected to the pallets is the pendulum (Fig. 6), and if we give it a swing it will cause the pallet B to lift up and will allow the tooth A to pass. By then the pallet C on the other side will have come in the path of the tooth D, and the pendulum on its return swing will lift that pallet up and this action is repeated over and over again. We now

come to an important point; the pendulum would eventually come to a standstill if it did not receive some impulse. The teeth of the escape wheel constantly pushing the pallets out of their way give the necessary impetus to keep the pendulum swinging and account for the tic-toc.

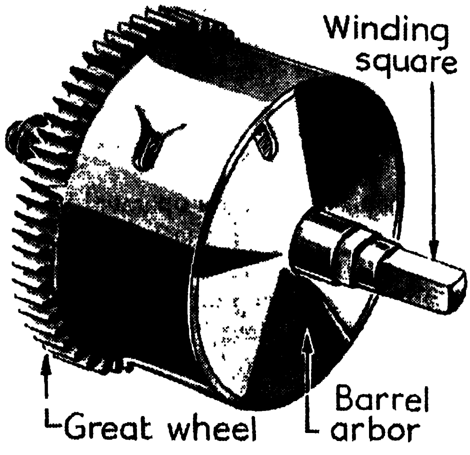
The number of teeth in the various wheels and pinions and the length of the pendulum are calculated so that the hands indicate the time, that is, the minute hand will revolve once in an hour, and the hour hand once in twelve hours (Fig. 7).



MECHANISM OF A STRIKING CLOCK

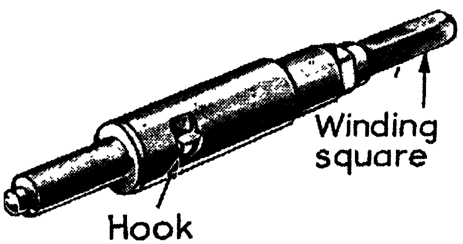
Fig. 1. There are various forms of regulators, or governors, for a clock; pendulum, balance or rotor. The motive power can be divided into three categories: spring-driven, weight-driven, and electrically-driven. This is a pendulum, spring-driven striking clock seen from the back.

The clock we are examining strikes the hours and half-hours, and this is brought about in the following manner. Another set of wheels, barrel and mainspring is used especially for the striking work. The separate parts illustrated are marked with the same numbers as in Fig. 8. We shall follow the clock striking the hours first. Fixed to the wheel 8a on the underside, are two lifting pieces and as this wheel rotates (by the power of the timekeeping part of the clock) the lifting piece B (Fig. 8a) will lift the lever 8b, and this in turn will lift the lever 8c. As a result the rack 8d will be released, and by reason of its weight and the position in which it is pivoted, it will fall, so that the arm attached to the rack will drop on to the snail 8e. This snail, fixed to the hour wheel (so named because of its similarity in shape to the snail), is graduated, so that if the rack is arrested by the highest or largest part of the snail, only one blow will be struck by the hammer on the gong, but if it falls to the lowest or smallest part, twelve blows will be struck. Equally, the corresponding number of blows will be struck when other parts of the snail come into operation. At this stage, however, the clock is not ready to strike, the lifting piece on the wheel 8a



THE CLOCK BARREL

Fig. 2. Into this round box or barrel, which is usually made of brass, the strip of hardened and tempered steel which provides the motive power is placed. Its property of returning to its original shape after being bent makes the clock work.

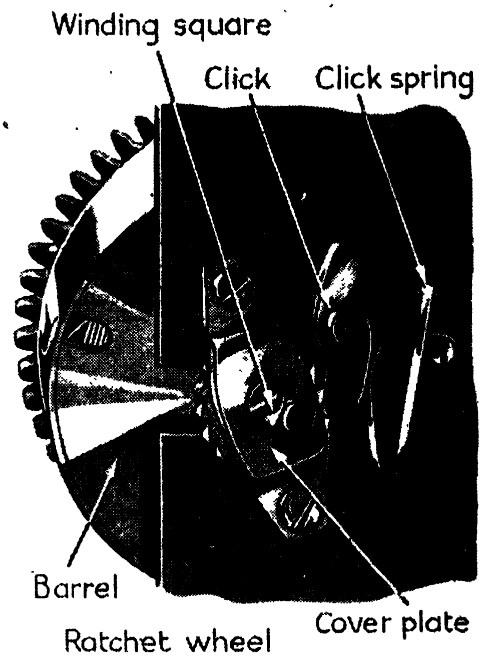


THE BARREL ARBOR

Fig. 3. The steel strip constitutes the spring. This mainspring is also wound round a steel piece called the barrel arbor, shown above. The arbor is held securely, after the spring is wound on to it and the other side of the spring, being secured to the side of the barrel, produces the tension which causes the barrel to revolve.

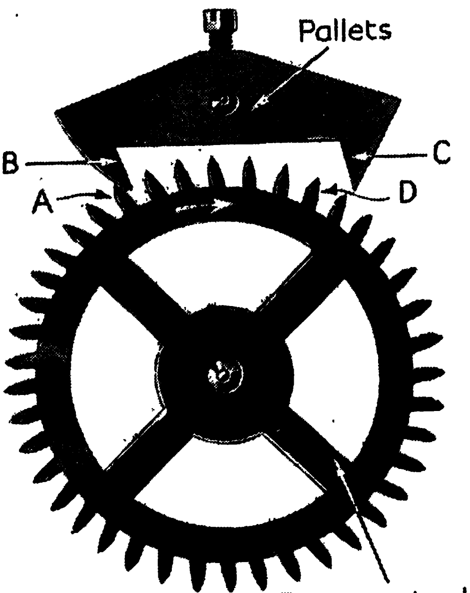
has not lifted the lever 8b high enough.

The action just described takes place at about five minutes to the hour, and the rack arm falling on to the snail accounts for the noise you hear at that time, and is known as the warning. Now, with the rack released ready, the lever 8b has brought the lever 8c into action, and on the lever 8b is a protruding piece A which comes into the path of a pin on the wheel 8f and stops the striking from proceeding.



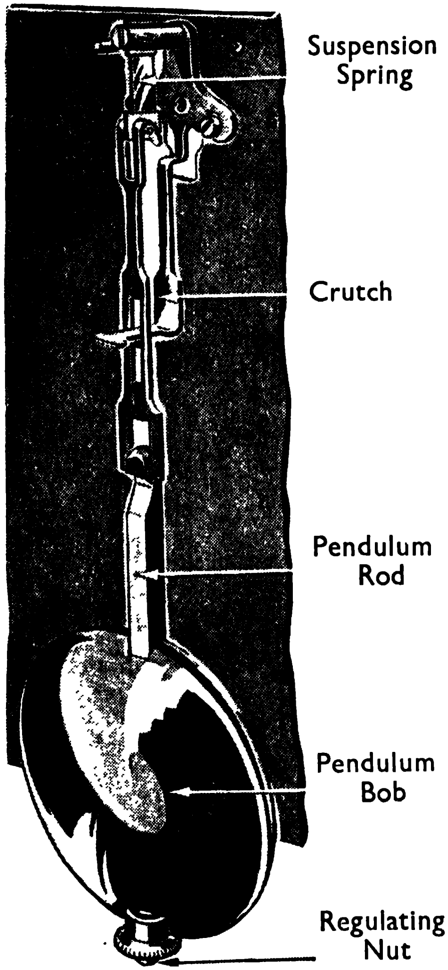
VIEW OF BARREL RATCHET WORK

Fig. 4. If the mainspring is wound up it will cause all the wheels and pinions which are geared with the barrel of the clock to rotate.



THE ESCAPEMENT

Fig. 5. The escape wheel and pallets here shown together form the escapement and allow the power of the mainspring to escape gradually.

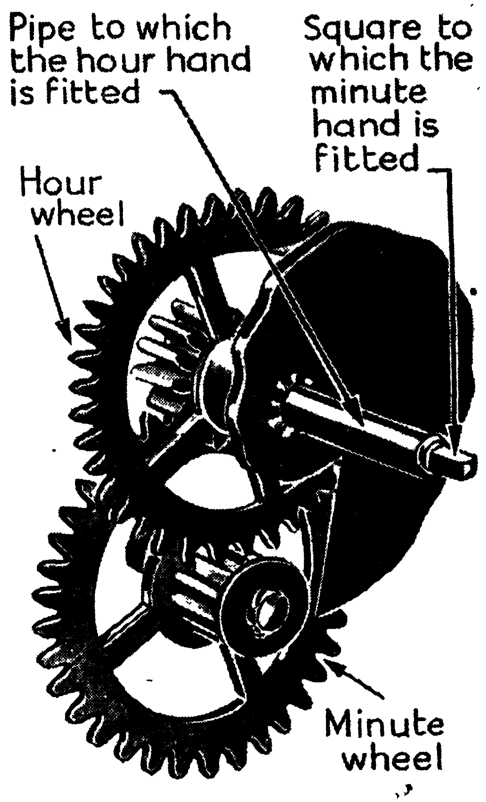


THE PENDULUM

Fig. 6. The pendulum is attached to the pallets, shown in Fig. 5. If we give it a swing it will cause the pallet B to lift and allow the tooth A to pass. On the return swing it will lift the pallet C and allow D to pass and so the movement continues. The teeth of the escape wheel provide the impetus of the pendulum

During all this the wheel 8a continues to rotate and, at the precise moment, the lifting piece attached to this wheel will allow the lever 8b to drop, which frees the wheel 8f and the striking proceeds. The piece 8g will now rotate and the pin on it will come into contact with the teeth on the rack. One revolution of this gathering pallet, as it is called, will gather up one tooth of the rack, and once it has been gathered, the lever 8c will prevent it slipping back. If the rack falls on to the smallest part of the snail, twelve teeth of the rack will pass the gathering pallet, and as each tooth on the rack represents one blow, 12 o'clock will be struck.

The actual striking is operated by the wheel 8i. The spiked wheel fixed to this wheel lifts the pin A on the piece 8h, and allows it to drop off suddenly (Fig. 9). Fixed to this piece 8h is the hammer which strikes the gong. When all the teeth of the rack have been gathered up, the lever 8c, which, during the striking, has been held up by the rack, will now drop and the protruding piece from it will come into the path of the step A

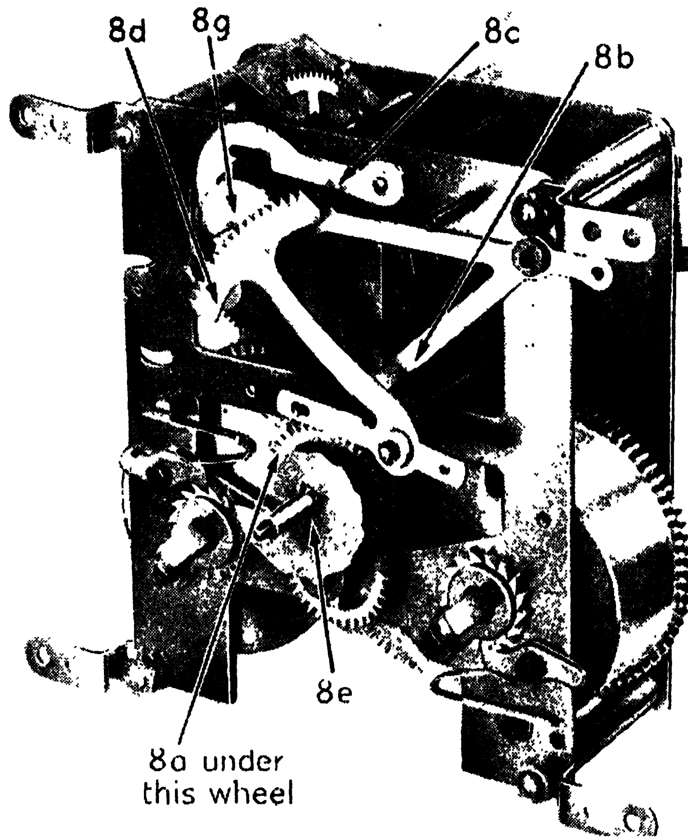


MOTION WORK

Fig. 7. The number of teeth in the various wheels and pinions and the length of the pendulum are calculated so that the hands indicate the time, that is, the minute hand revolves once in an hour and the hour hand will similarly revolve once in every period of twelve hours

on the gathering pallet 8g, and so stops the striking.

The half-hours are struck as follows: there are two lifting pieces on the wheel 8a, one shorter than the other, and the shorter one B will not lift the lever 8b as high as the other lifting piece, but high enough to release the wheel 8f, and one blow only will be struck at once. The warning part does not come into operation at the half-hours. The reason for the warning is that the rack is given time to fall and settle down, especially the long hours, so that all is ready when the exact moment comes for it to strike.



PARTS OF THE STRIKING CLOCK

Fig. 8. This clock strikes the hours and half-hours, and a set of wheels, barrel and mainspring is used especially for the striking work. The separate parts are shown in following diagrams numbered to correspond with those above and describing their functions in more detail.

Chiming clocks are distinct from striking clocks although one finds sometimes that the latter are referred to as chiming clocks.

Fig. 10 shows the mechanism with the dial or face removed. The chime part of the mechanism is released first, and this is brought about in the following manner. The wheel 10a has four lifting pieces attached to it, and as this wheel indirectly carries the minute hand, it makes one complete revolution in an hour. Therefore, the chime is brought into operation every fifteen minutes.

The lever 10b releases the chime mechanism in a similar manner to the strike mechanism just described. It will be noted that this lever has a hole at the end and to this is attached a cord so that the last quarter and the hour can be made to chime at will by pulling the cord. The chime is released by the projecting piece B on the lever 10c being lifted out of the notch B on the piece which is fixed to the wheel 10d and similar to the striking clock. The chime is not yet free to proceed; the pin C in the wheel 10d is arrested by A on the rod of the lever 10c, and not until the lever drops, by reason of the lever 10b being released by the lifting piece 10a, will the chime proceed. The piece 10e now revolves, and it will be noted that it has notches

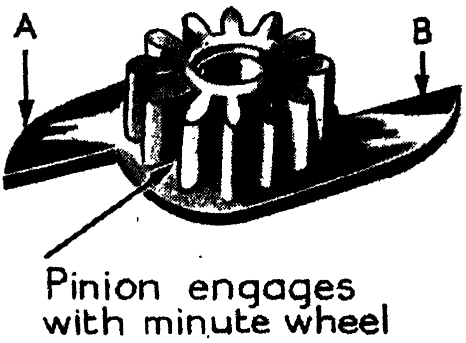


Fig. 8a. Fixed to the wheel 8a are two lifting pieces and as this wheel rotates the lifting piece B will lift the lever 8b which in turn operates 8c.

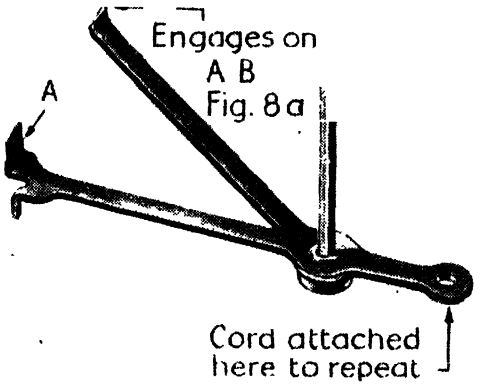


Fig. 8b. This is the lever which engages on AB Fig. 8a. The piece A, above, engages on 8f.

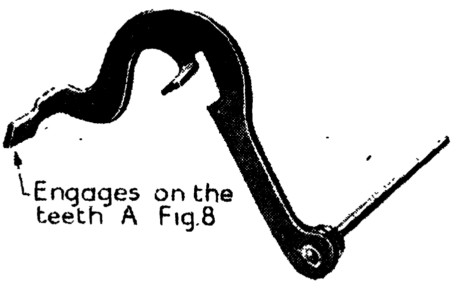


Fig. 8c. The lever 8b in turn lifts lever 8c. As a result the rack 8d will be released.

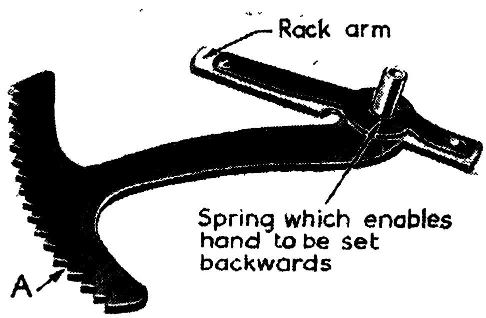


Fig. 8d. When the rack 8d (above) has been released the arm attached will drop down on the snail 8e. This snail, fixed to the hour wheel, is graduated so that if the rack shown above is arrested by the highest or largest part of the snail, only one blow will be struck by the hammer, at other parts more.

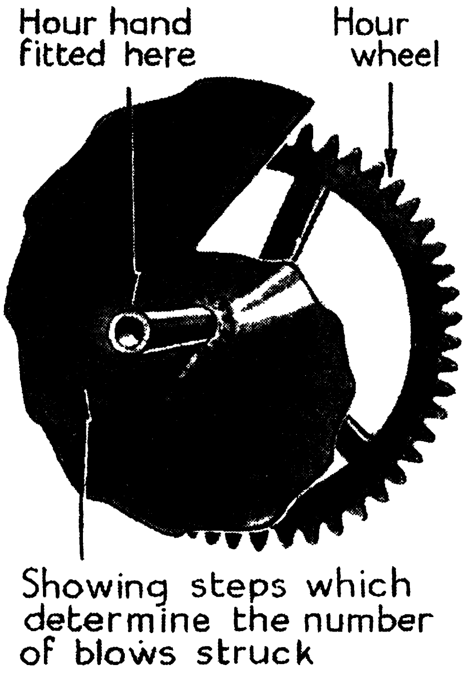


Fig. 8e. This is the snail, so called from a fancied resemblance to a snail. The rack arm falling on it about five minutes before the hour gives a familiar sound, the warning before the strike.

cut into its edge; the distance apart of these notches controls the length of the chiming. The shortest section allows one quarter to chime, the next, two quarters on the half-hour, next, three quarters, and the longest section four quarters denoting the hour. The piece B projecting from the lever 10c operates on the edge of 10e, and when the chime is complete this projecting

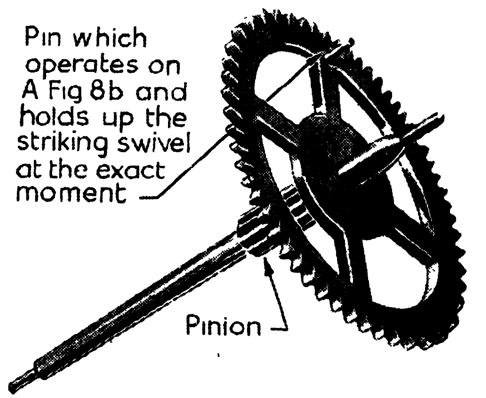


Fig. 8f. The wheel 8a has continued to rotate and at the right moment the lifting piece attached allows the lever 8b to drop, which frees the wheel 8f and the striking proceeds. The pin to hold up the striking is seen above.

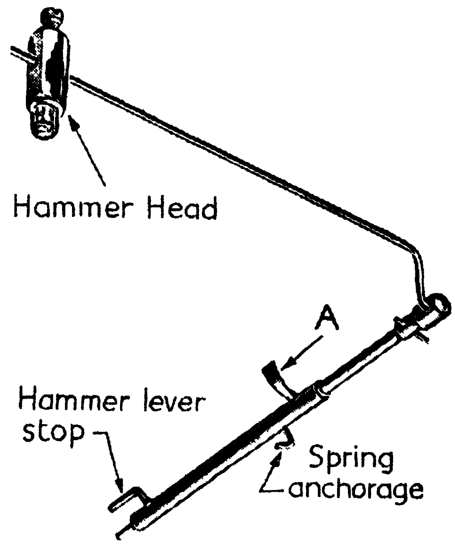


Fig. 8h. Fixed to this piece 8h is the hammer which strikes the gong. The spiked wheel fixed to 8i lifts the pin A on 8h and allows it to drop off suddenly. The attachment of this piece can be seen from Fig. 9 on the following page, which shows rod, hammer spring and hammer stop and the position it occupies in the clock.

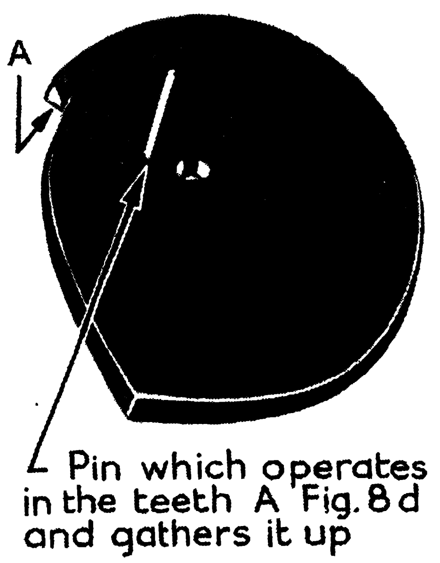


Fig. 8g. This piece called the gathering pallet now rotates and the pin shown comes in contact with the teeth of the rack. If the rack falls on the smallest part of the snail twelve teeth of the rack will pass the gathering pallet and as each tooth on the rack, shown in Fig. 8d, represents one blow, twelve o'clock will be struck.

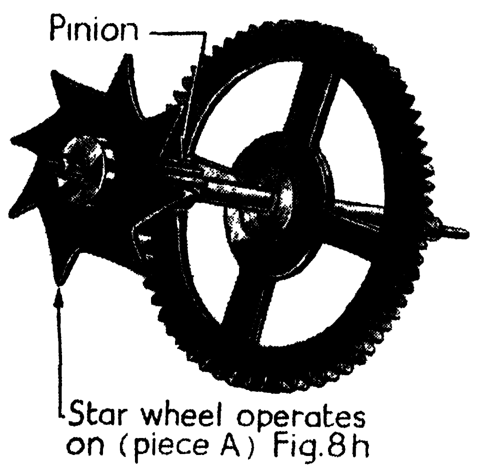


Fig. 8i. This wheel operates the actual striking. The spiked wheel fixed to this wheel lifts the pin on the piece 8h, and it is the sudden drop-off which causes the hammer to strike the gong.

piece drops into the notch and so stops the chime from proceeding further, as it causes the projecting piece A on the same lever to come into the path of the notch in the piece B (Fig. 10d).

Now at the hour the chime proceeds as usual, the piece 10e rotates, and on its outer edge rides the lever 10c, and the highest part A will lift the lever 10c up and this will release the striking part

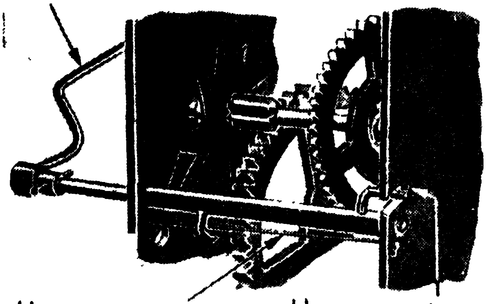
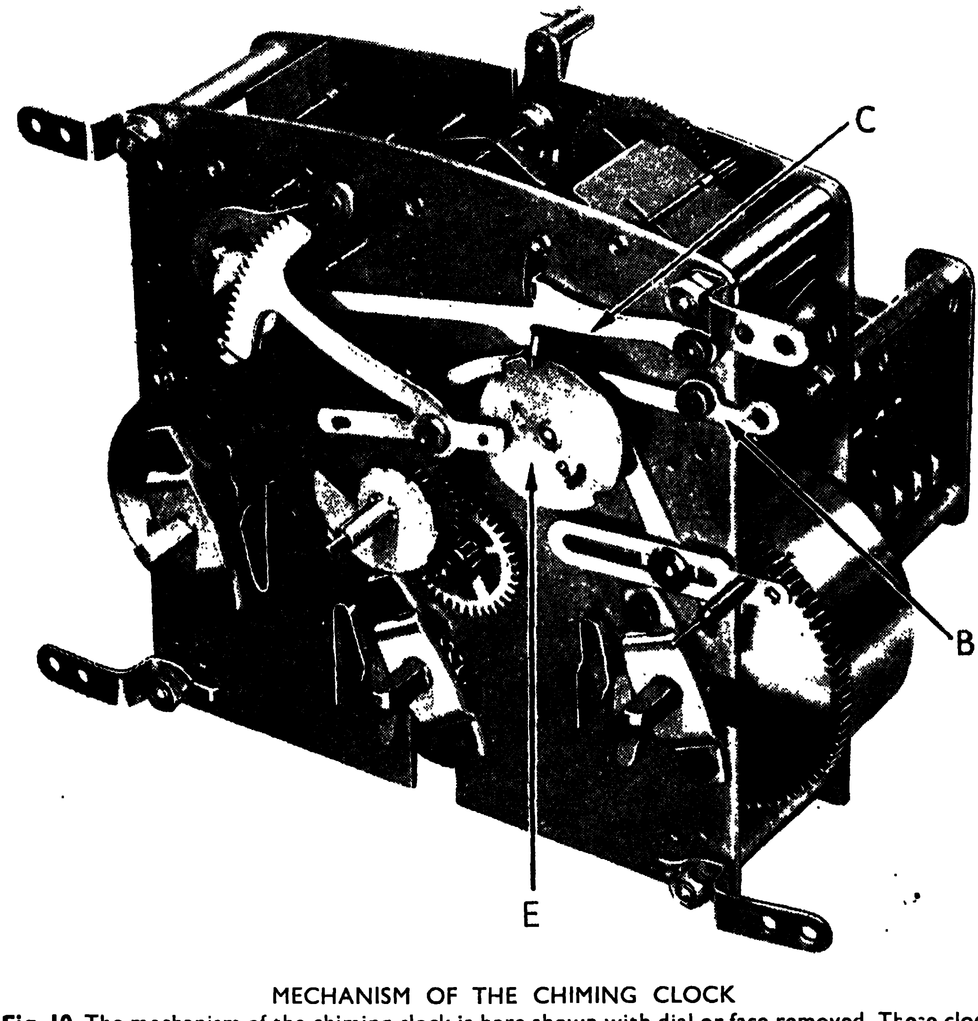


Fig. 9. The hammer attachment in position.

of the mechanism in a manner similar to that described when dealing with the striking clock. The projecting piece C on lever 10C arrests the strike until the chime is complete and as it lowers into the notch on the locking plate 10E shown on the opposite page, the strike is free to proceed. You will see, from the above description that the exact time at the hour is the first stroke of the strike and not of the chime. This is also true of all public clocks that chime, the principle being the same.



MECHANISM OF THE CHIMING CLOCK

Fig. 10. The mechanism of the chiming clock is here shown with dial or face removed. These clocks are distinct from striking clocks, though the latter are sometimes referred to as chiming clocks and there are similar features in their operation. The sequence of events is shown on opposite page

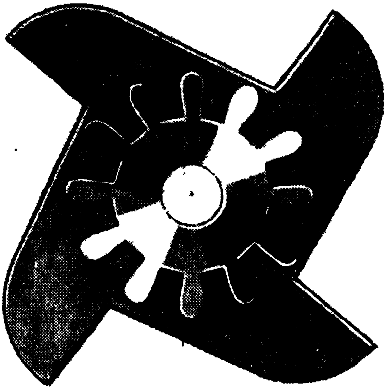


Fig. 10a. This wheel has four lifting pieces attached. It brings the chime into operation.

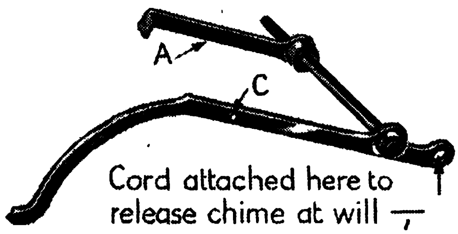


Fig. 10b. This lever releases the chime mechanism in a similar fashion to the strike mechanism.

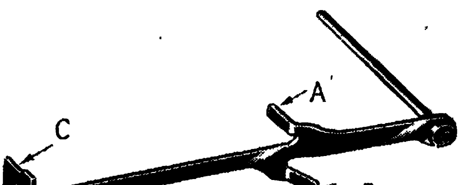


Fig. 10c. B on this lever is lifted out of the notch B. (Fig. 10d). This piece fits at C, (Fig. 10).

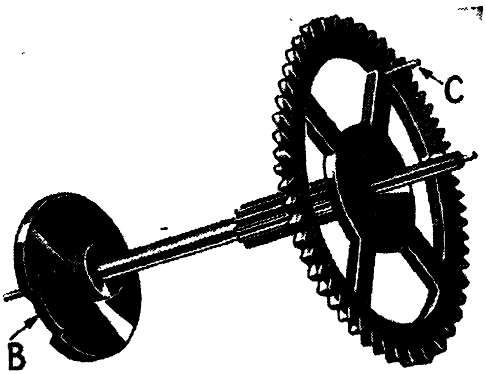


Fig. 10d. This wheel controls the chime.

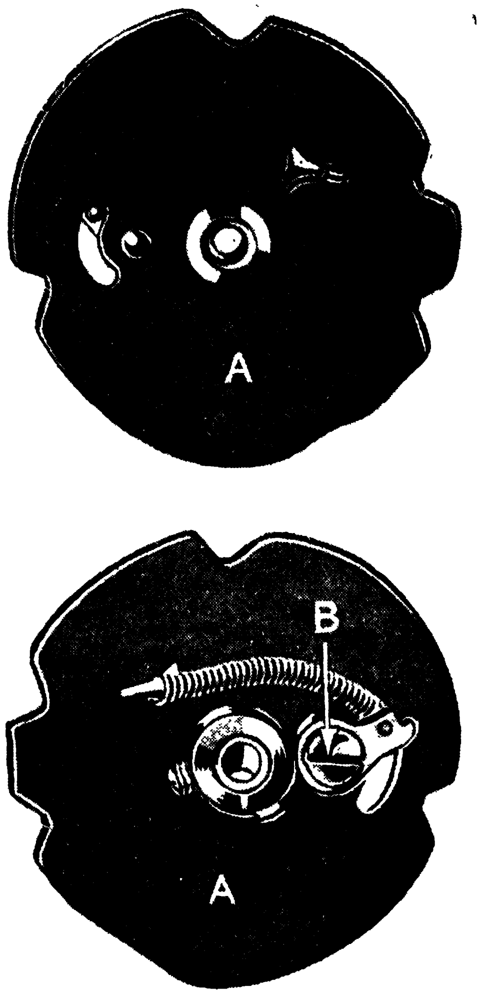
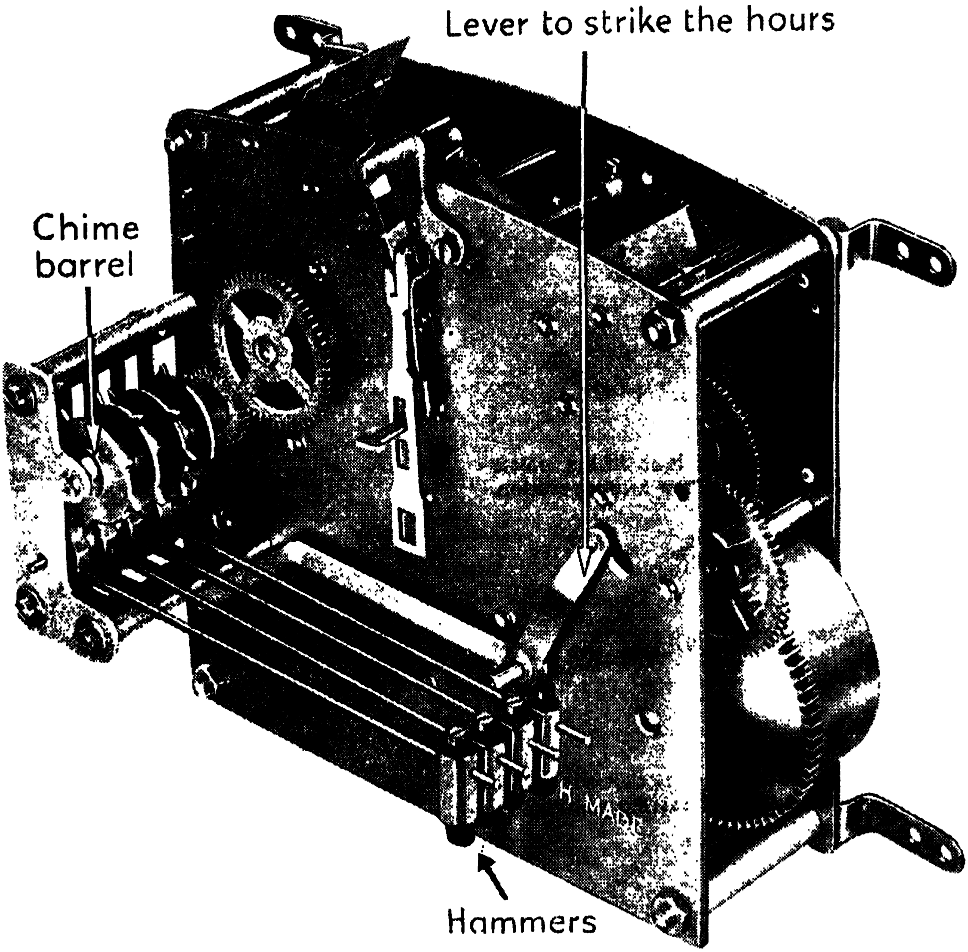


Fig. 10e. This is a form of locking plate, its two sides being shown above. It is seen at E (Fig. 10). After the lever 10b has been released by the lifting piece as in Fig. 10a the chime proceeds and this piece now revolves. The notches cut into its edge are set apart at a distance which controls the length of the chiming. The shortest section allows one quarter to chime, the next, two quarters on the half-hour, next, three quarters and the longest section four quarters denoting the hour. The piece B (Fig. 10c) operates on the edge of 10e and when the chime is complete this projecting piece drops into the notch and so stops the chime from proceeding further as it causes the projecting piece A on the same lever to come in the path of the notch in the piece B (Fig. 10d). Action of the lever (Fig. 10c) on 10e above releases the striking part of the mechanism. The piece C (Fig. 10c) arrests the strike until the chime is complete, the exact time being given by the first stroke of the strike and not by the chime which precedes it.

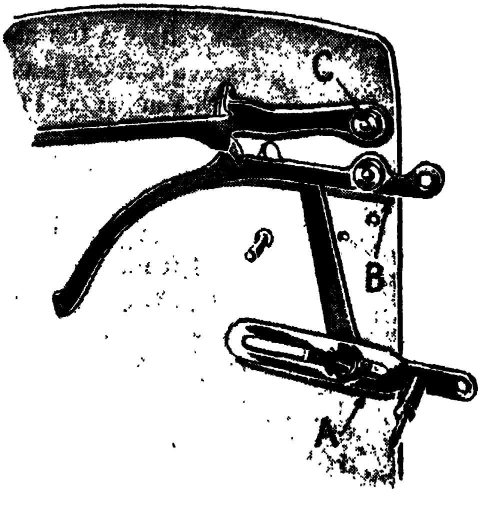


HOW THE CHIMING IS BROUGHT ABOUT

Fig. 11. The chime is made by the barrel here illustrated. The spikes shown lift the hammers one at a time and allow them to drop suddenly. The striking of the hours is operated by the lever indicated. The lever lifts two hammers at the same time and allows them to fall with a chord effect.

It may have been noticed that some chiming clocks correct themselves automatically should they get out of sequence, i.e., chime the wrong notes, and this is brought about by the simple and clever device on the reverse side of the piece 10e. At the three-quarters section the small lever B on the piece (10e) comes into contact with the pin B on the lever 10b, and it holds the lever up on the notch or step cut there for that purpose. The result is that it is not until the hour-lifting piece, which is a little longer than the other three, comes into operation that the lever 10b is lifted high enough to free the lever B 10e from the pin B 10c. Therefore, if the chime is out of sequence no quarters at all will be sounded until the hour comes along and then the correct tune is played.

The actual chiming is brought about by the barrel here illustrated (Fig. 11). The spikes shown lift the hammers one at a time and allow them to drop suddenly. The striking of the hours is operated by the lever indicated. This is

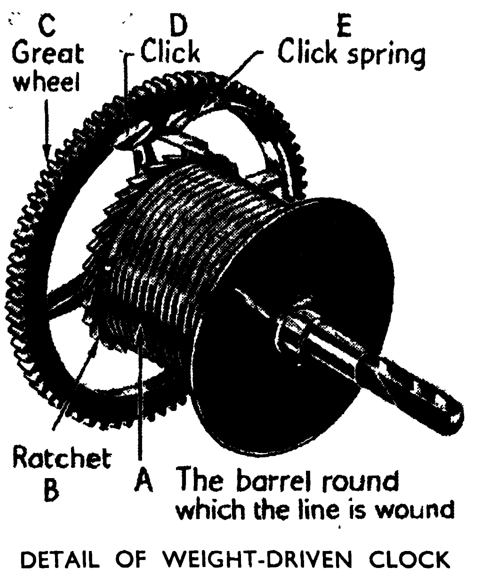


STOPPING CHIME AND STRIKE

Fig. 12. Should it be desired for the chime and strike not to operate, the lever A is pressed down and this holds B and C (the same as B and C in Fig. 10) up out of the way so that the lifting pieces are thus unable to make contact.

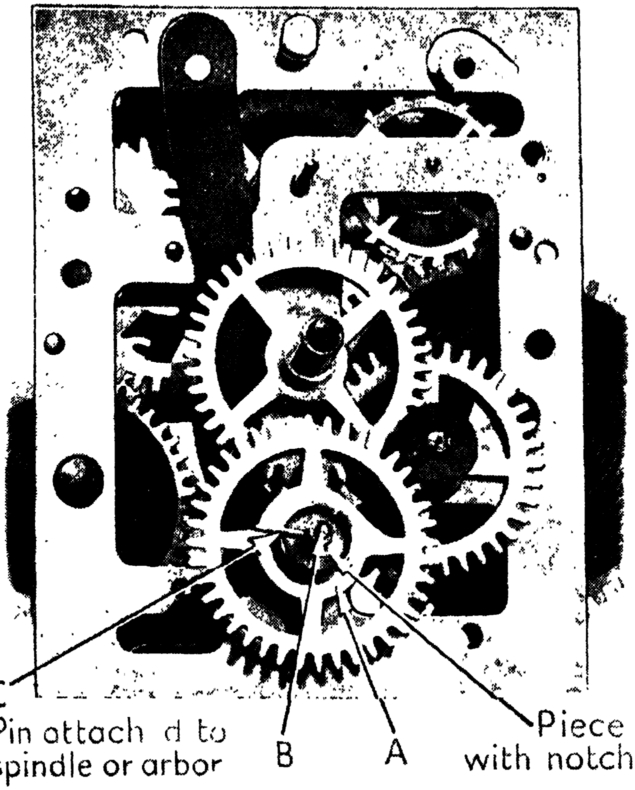
lifted by a spiked wheel, in a similar manner to the striking clock described; this lever lifts two hammers at the same time and allows them to fall together which results in a chord effect. Should it be desired for the chime and strike not to operate, the lever A (Fig. 12), is pressed downwards and this holds the levers B and C (which are the same as 10B and 10C) up out of the way, so that the lifting pieces do not make contact, and the chime and strike mechanism is held up in consequence.

As the name implies, weight-driven clocks are driven or made to go by the fall or pull of a weight. Apart from the motive power and its application, weight-driven are precisely similar to the spring-driven clocks we have discussed previously. As a matter of interest, the first clocks made, about the middle of the fourteenth century, were weight-driven. The manner in which they work is simple. Instead of the mainspring being inside the barrel, a line of some description, generally catgut, is wound round the outside of the barrel, and to this line a weight is attached. It will be seen that some special arrangement must be provided to enable the line to be wound round the barrel or drum. Fig. 13 shows the barrel of an English grandfather clock, and the principle employed there is the same in all weight-driven clocks. A is the barrel round which is wound the line; attached to this barrel is the ratchet wheel B; unlike the spring-driven barrel the wheel C is not fixed to the barrel itself. Attached to the great wheel C, is the click D, and the spring E operates on the click. The barrel ratchet engages the click, so that when the barrel is wound up the wheel C will not move, but the pull of the weight will cause the click to transmit the power of the weight to the wheel C, and so drive the clock.



DETAIL OF WEIGHT-DRIVEN CLOCK

Fig. 13. The clock here referred to is driven by the fall or pull of a weight. In this case, instead of the mainspring being inside the barrel, a line of catgut is wound round the outside and a weight attached. Above is shown the barrel of an English grandfather clock. A is the barrel to which ratchet wheel B is fixed. Attached to the great wheel C is the click D on which the spring E operates. B engages D so that when the barrel is wound C will not move, but the pull of the weight will cause D to transmit the power of the weight to C and so will drive the clock



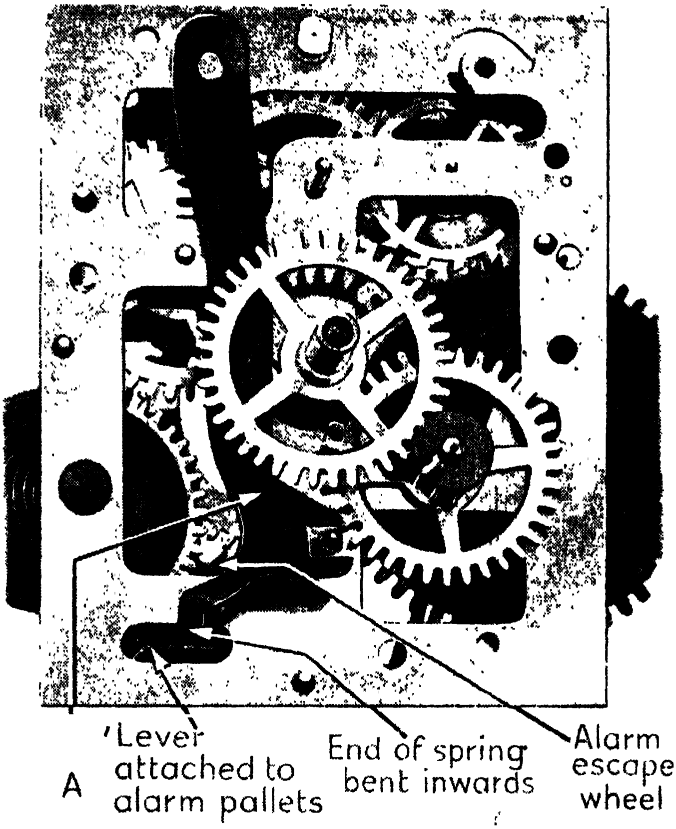
ALARM CLOCK WITH DIAL REMOVED

Fig. 14. The principle of all alarm clocks is much the same. A notched piece is attached to the wheel A. One side of the notch is straight, the other slopes. Through the centre of the wheel is a spindle or arbor B with a pin C projecting. The wheel makes a revolution in twelve hours. B remains stationary. When the straight side of the notched piece comes to the pin C it allows the wheel A to spring up suddenly.

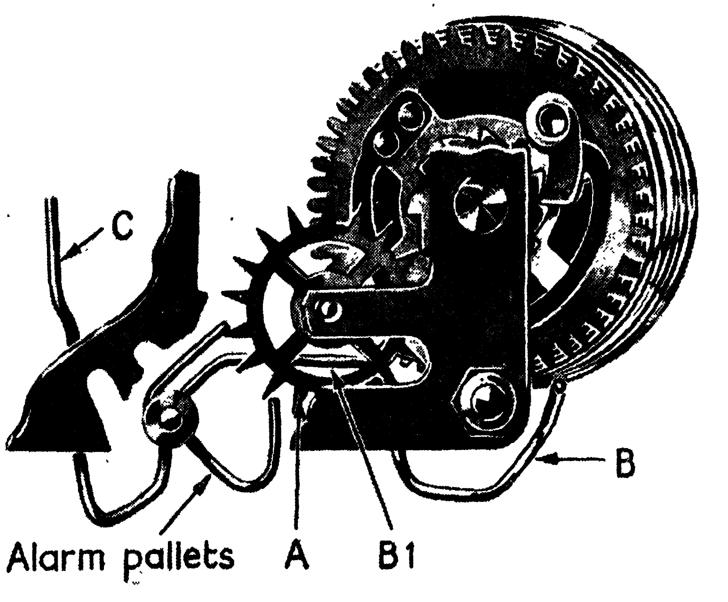
The advantage of weight-driven clocks is that the power transmitted is constant. The disadvantage is that such clocks are not portable and, further, they need more space as regards length of case. A spring-driven clock, even with a pendulum, can be moved from one room to another with comparative ease and safety. A weight-driven clock, on the other hand, would have to be dismantled.

It is true to say that everyone is familiar with the alarm clock in some form or another. The active principle of the alarm work is practically the same in all alarm clocks. Fig. 14 shows an alarm clock with the dial removed. Just what happens is this: the wheel A has attached to it the piece with a notch cut into it; one side of this notch is straight and the other side is a gradual slope up until it merges into the main part. Through the centre of this wheel is a spindle or arbor B which has a pin C projecting from it. This wheel is spring-loaded, and it revolves with the mechanism of the clock, making one complete revolution in twelve hours. The spindle, or arbor, through the centre of the wheel remains stationary and the wheel travels in the direction as indicated by the arrow. When the straight side of the notched piece comes to the pin in the spindle it allows the wheel to spring upwards suddenly. Now under the wheel A is the spring (Fig. 15), and the end of this spring is bent inwards so that it projects into the path of the lever, which is attached to the pallets (Fig. 16). When the wheel jumps up it allows the projecting piece of the spring to disengage B 1 (Fig. 16) from the lever on the pallets and so releases the alarm set of wheels. The escape wheel A (Fig. 16) revolves quickly and causes the pallets to wag backwards and forwards. There is no pendulum to control it as there is in the clock escapement. Also attached to the pallets is a lever (C) with a hammer,

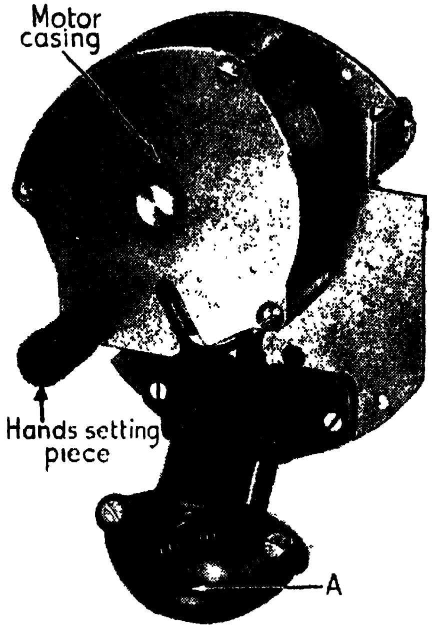
and this hammer strikes a bell or gong rapidly and makes the alarm to sound. The lever B I terminates as shown in B when the alarm has been running for some time. The main-spring unwinds, eventually pressing on the lever B, which then stops the alarm. This device has the effect of making the alarm sound at a more or less regular speed; if it were not for the lever B the alarm would sound for a longer period and the end would be very slow. At the other end of the spindle B (Fig. 14) the alarm hand is attached, so that if



HOW THE ALARM CLOCK RINGS
Fig. 15. Under the wheel A (Fig. 14) is the spring here shown whose end is bent inwards into the path of the lever attached to the pallets.

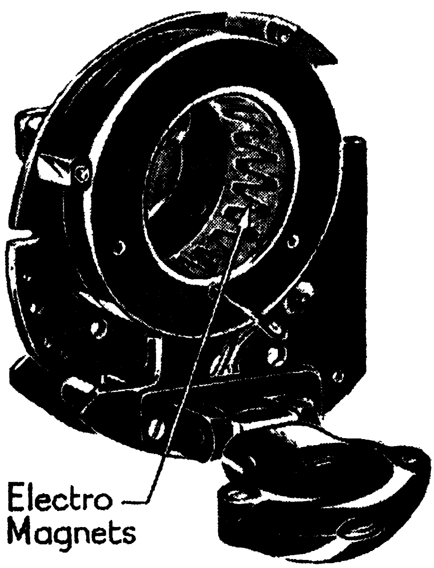


DETAIL OF ALARM
Fig. 16. The spring disengages BI from the pallets. The escape wheel A revolves and causes the pallets to wag to and fro. A hammer is attached to lever C which strikes a bell or gong. The lever BI ends as shown in B when the alarm has been running for some time. The main-spring unwinds, presses on B and stops the alarm. The alarm hand is attached to B (Fig. 14) so that the wheel A (Fig. 14) jumps at the time set. After the alarm is finished A (Fig. 14) still rotates and the wheel is pressed down again and with it, spring and projecting piece.



BACK VIEW OF AN ELECTRIC CLOCK

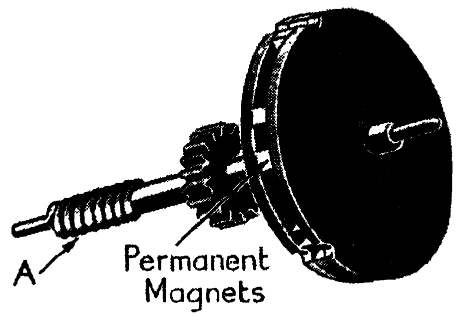
Fig. 17. The plug A of this synchronous motor clock is connected with the mains and operates the startor seen in the following diagram.



STARTOR OF THE ELECTRIC CLOCK

Fig. 18. The teeth of the startor shown above are the electro-magnet. The electro-magnet is stronger than the permanent magnet so that when the power is on, the startor teeth pull the rotor teeth round one segment or tooth and the movement then becomes alternate.

the spindle with the pin attached to it is set to a certain time, the wheel A (Fig. 14) will jump up at that time and the alarm will be sounded. After the alarm is finished, the wheel A (Fig. 14) still rotates, and, owing to the gradual slope already referred to, the wheel will be pressed downwards and with it the spring with the projecting piece. This projecting piece will again come in the path of the alarm pallets and will remain there for twelve hours, unless the alarm indicating hand has been altered by means of the spindle. It will be necessary to wind the alarm mainspring again for the alarm to sound, because the full extent of the spring is used at each

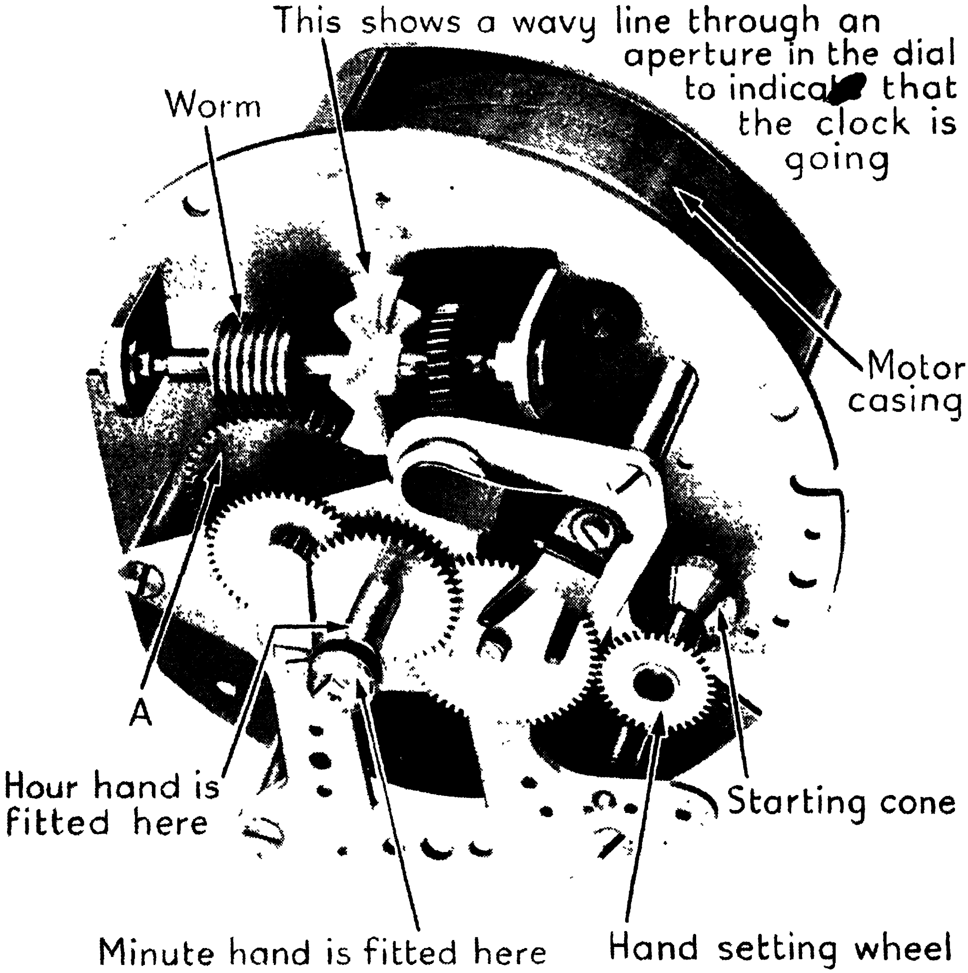


ROTOR SPINDLE

Fig. 19. Attached to this piece is a worm A, which gears into the fibre wheel to ensure silent running. *See also* the photograph (Fig. 20).

alarm, unless it is stopped by the operator. Incidentally, alarm clocks were, it is reputed, the first clocks. The alarm sounded as an indication that a bell was to be sounded manually. They were not clocks as we know them, but measured a passage of time between two intervals, such, for example, as between two occasions of call to prayers.

The electric clock we shall consider here is the kind you plug into the mains, known as synchronous motor clocks. These clocks are entirely different from those we have discussed previously, in fact they are not clocks at all, from the clockmaker's point of view, but are



MECHANISM UNDER THE DIAL OF AN ELECTRIC CLOCK

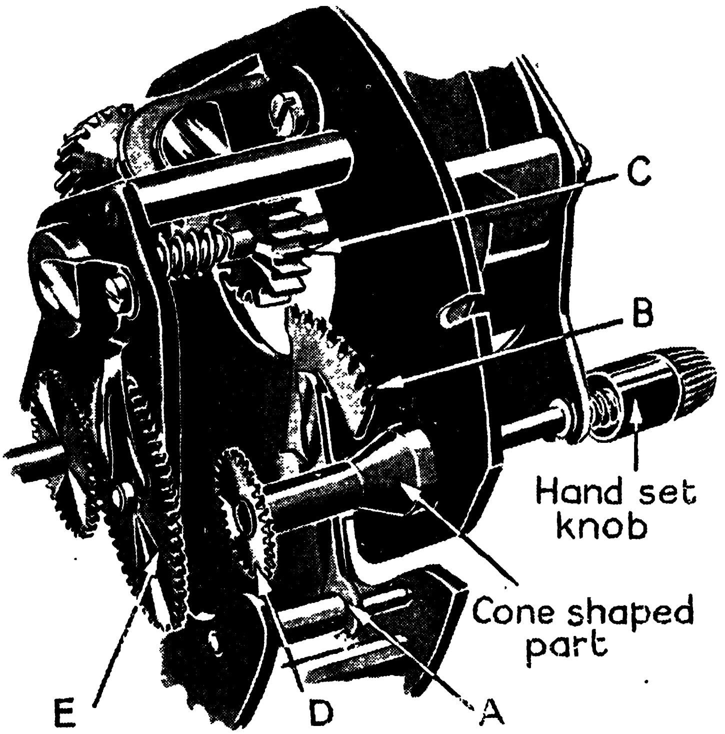
Fig. 20. The fibre wheel A gears with the worm on rotor spindle. It operates other wheels and by suitable gearing the hour hand revolves once in twelve hours and the minute hand once an hour

meters. As we shall see presently, it is not possible to regulate these timepieces; they are controlled from the electric power station. The Board of Trade stipulates that the alternating current distributed shall be of a certain regularity or consistency. Further, electricity companies find that accuracy of the alternations is essential to the correct working of the grid system. These two factors make it possible to use a.c. power as a time-telling medium. The accuracy of the a.c. power is incidental to clocks and not because of them. For these clocks to function, therefore, it is essential that the power shall be a.c. time controlled; d.c. power will not do. If the a.c. were not time controlled, the clock might show a considerable variation in timekeeping.

Let us just see what happens at the power station, before we take a look at the clock. The turbines are manually controlled, so that the power distributed synchronizes with a standard timekeeper. The power leaving the station is, for all

domestic purposes, accurate, and if it is used to make a motor revolve, and that motor is suitably geared, etc., we must have *accurate* time. We have put accurate in italics because for scientific purposes the time recorded is not accurate; the turbines at the power station are constantly being adjusted to suit the output, and if we were to take a short period of, say, fifteen minutes, we may find an error of several seconds, but over a longer period that error would be corrected. The turbines are constantly being made to run faster or slower and, therefore, our clock is either fast or slow, only a few seconds it is true, and at moments the clock is exactly right, but on the day's running we can say that it is exact.

Fig. 17 shows the inside of a synchronous motor clock. The plug A is connected to the mains and this operates the startor. Fig. 18 shows the inside of the startor with the rotor (Fig. 19) removed. The teeth-like pieces are the electro-magnet, and as the a.c. passes through, these teeth are energized and become magnets. The rotor (Fig. 19) also has teeth, but these are permanent magnets. The electro-magnet is stronger than the permanent magnet, so that when the power is on, the startor teeth pull the rotor teeth round one segment or tooth only. By that time the power has become minus and the permanent magnet on the rotor comes into operation. The rotor teeth are attracted by the now dormant teeth of the startor, which cause the rotor to move forward one segment; by then the current becomes plus again, and the electro-magnet pulls the rotor round one segment again, and so it goes on, fifty times every second, first the electro-magnet and then the permanent, and it is this action which makes the rotor step forward. Attached to the rotor spindle is the worm A (Fig. 19) which gears into the fibre wheel A (Fig. 20). This wheel operates others, and by suitable gearing the hour hand is made to revolve once in twelve hours and the minute hand once in each hour.



STARTING AN ELECTRIC CLOCK

Fig. 21. It is necessary to set the rotor in motion to start an electric clock. To do this the hand-setting knob must be given a smart push and this will cause the cone-shaped part of the hand-set spindle to impinge on lever A which presses on rack B which in turn engages wheel C which is attached to the spindle of the rotor and sets it in motion. To set the hands, the hand-set piece is pushed forward, and D engages the wheel E. On releasing the knob, D is disengaged.

HOW YOUR REFRIGERATOR WORKS

The meaning of refrigeration. Its advantages for preserving perishable food. The parts of a refrigerator. Water-cooled safes. Ice boxes. The compression and absorption types of refrigerator

Of the many advantages which science has brought to the home in recent years, refrigeration is surely one of the most valuable as it is not only a contribution to our comfort and enjoyment, but a very important aid to our health and economy.

Many people confuse freezing with refrigeration. The production of ice is not necessarily the function of a domestic refrigerator. The accepted meaning of refrigeration is the science of maintaining a space at a temperature lower than that of its surroundings. The object of a refrigerator in our home is to keep food at a temperature which will preserve it in the best possible condition for a reasonable period of time. This object is achieved if the temperature at which food is stored is kept at 50 degrees Fahrenheit, or below. This is a good deal higher than the freezing point of water, which is 32 degrees Fahrenheit.

MEANING OF REFRIGERATION

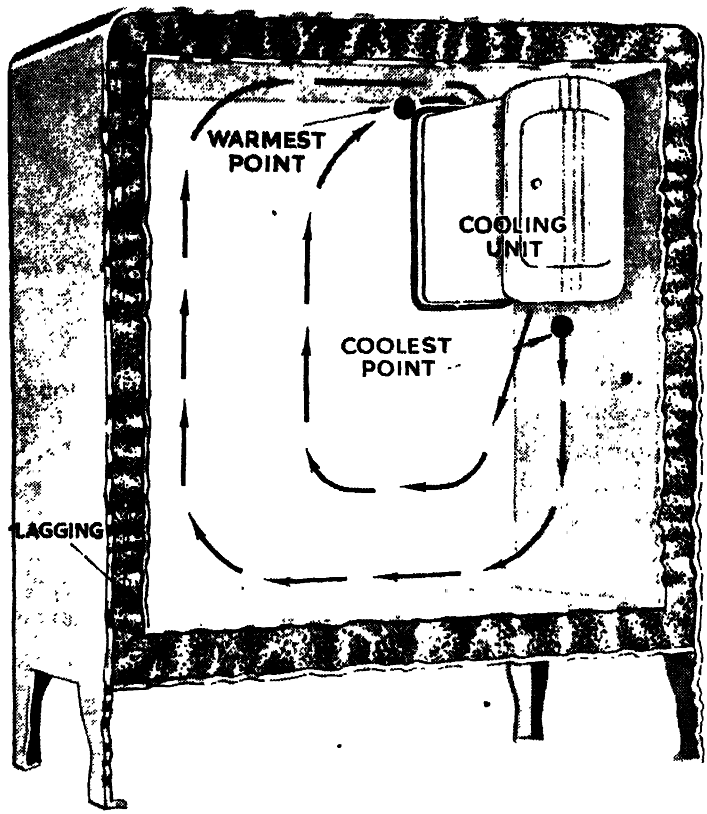
Most domestic refrigerators, however, also produce ice, but it should be remembered that, while ice is a pleasant and sometimes useful product of the apparatus, it is not its primary function.

For many years certain of our perishable foodstuffs were preserved by chemical means. But the medical profession found that the use of even the minute quantities of certain chemical preservatives used produced undesirable effects on human beings over a prolonged period of time. In 1928 a Food Act came into force which prohibits the use of all chemical food preservatives with certain specified exceptions. The effect of this law has been to ensure the sale of pure fresh food which, however, will not keep long if the temperature is above 50 degrees Fahrenheit.

WHY FOOD DECOMPOSES

The reasons why food becomes tainted or decomposes are well known. Even in perfectly fresh food various micro-organisms are present to a limited extent, and they are also present in the atmosphere. Most of these organisms are quite harmless bacteria which, in quantity, would affect the flavour and make the food unpalatable, but not render it harmful. This is not all, however, because there may also be present disease bacilli such as those of tuberculosis and typhoid which, if allowed to multiply, would render food harmful to health even before it became unpleasant to the taste.

At normal temperatures these micro-organisms multiply in perishable food at an amazing rate. In fact, certain foodstuffs provide the ideal breeding ground at temperatures between 60 degrees and 100 degrees Fahrenheit. The following figures show what happens in milk at two different temperatures. The effect of temperature is very obvious.



WHAT HAPPENS IN A REFRIGERATOR CABINET

Fig. 1. The essential parts of a refrigerator are the insulated cabinet and the cooling unit. As the tendency of warm air is to rise the cooling unit is not placed at the bottom but at the top. The air nearest to it thus becomes dense and falls to the bottom and so circulation takes place in a downward direction as may be seen from our diagram.

Temperature at which milk is kept	*Relative number of bacteria after*			
	0 hrs.	12 hrs.	24 hrs.	48 hrs.
50 deg. F.	1	1.5	4.5	6
68 deg. F.	1	24	6,128	357,500

Thus we see that while at 50 degrees one bacterium increases only to six in forty-eight hours, at the normal summer room-temperature of 68 degrees it will multiply to over a third of a million!

There are three ways of killing or arresting the breeding of bacteria in food. They are: chemical preservatives; sterilization and refrigeration.

We have already seen that the first method—the use of chemical preservatives—is not the best, and is now for the most part not allowed by law. The second method is not always convenient and is likely to affect the flavour of food. At temperatures at or approaching the boiling point of water most bacteria are killed. This is why milk is pasteurized and household vessels scalded. But immediately after sterilizing, food must be completely sealed off from the air which would introduce bacteria, multiplying rapidly in the warm food. The third method, refrigeration, does not kill the bacteria, but keeps them in a comatose condition. At 50 degrees Fahrenheit breeding is practically arrested and becomes progressively slower as the temperature falls.

There are several ways in which we can obtain refrigeration cheaply in the home, but whatever method is employed it will be found that the refrigerator consists of two essential parts—an insulated box or cabinet in which the food is stored, and a cooling unit which is in contact with the air inside the cabinet.

A cooling unit works in a number of ways, but each serves the same purpose—to remove heat from the inside of the

cabinet. Now cold air is heavier than warm air, and hence, in a confined space such as the cabinet, the cold air will fall to the bottom and the warmer air will rise to the top. If the cooling unit were placed in the bottom of the cabinet, the air at the bottom would be cold, of course, but the air at the top would remain relatively warm. It would be rather like putting the kitchen water heater up in the roof—the hot water would not circulate downwards, it would remain at the top. For this reason the cooling unit is always fitted at the *top* of the cabinet. The air nearest to the cooling unit thus becomes dense and falls to the bottom of the cabinet, and so circulation takes place in a downward direction (Fig. 1). Various foods are kept in the cabinet at the same time, and some of these foods will, no doubt, vary in odour. Certain foods, particularly dairy produce, are susceptible to tainting because they readily absorb odours from adjacent foods. But, as the cooling unit is at the top of the cabinet, we are able to put the circulation of air to further use if we arrange our food in the cabinet in a careful manner. This is seen in Fig. 2, where foodstuffs are placed in the direction of air circulation. One complete circulation starts at the cooling unit, the frost on which acts as a deodorizer. Hence, food of strong odour should be placed towards the end of the circulation and food that is easily contaminated at the beginning.

On all types of refrigerator the cabinet is very effectively insulated or lagged to prevent heat entering from the surrounding air. In addition, it is airtight when the door is closed so that the cold air cannot leak out and be replaced by warm air from outside. For this reason

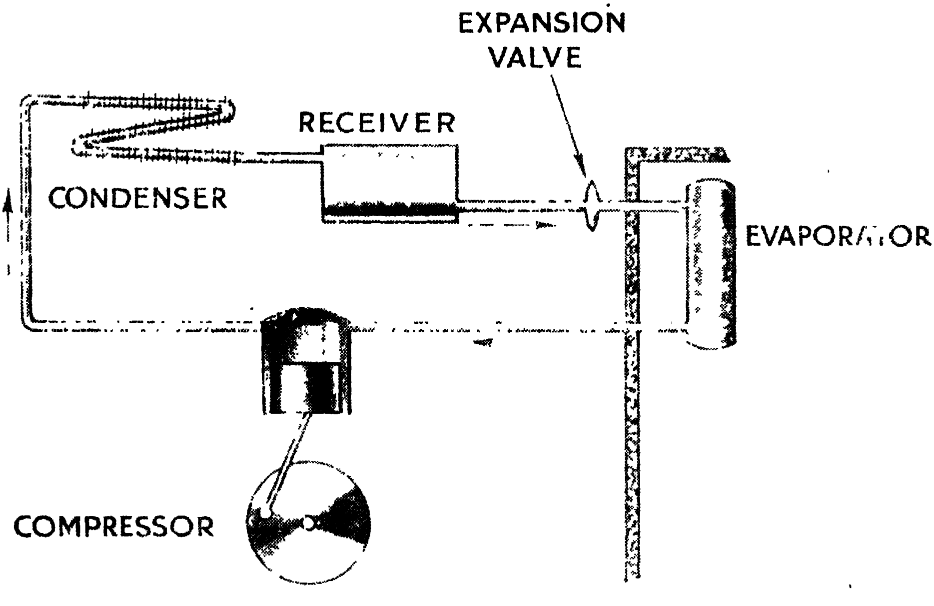
THE RIGHT WAY TO PLACE FOODSTUFFS IN A REFRIGERATOR

Fig. 2. The circulation of air shown in Fig. 1 can be turned to effective use by the careful arrangement of food. Certain foods are liable to taint because they absorb odours from adjacent foods. A complete circulation starts from the cooling unit, the frost on which acts as a deodorizer. Hence, food of strong odour should be placed at the end of the circulation and food easily contaminated, as dairy produce is, at the beginning. The artist has envisaged cream, butter, milk, a joint, eggs, fruit, cheese etc., placed inside the cabinet in their due rotation

it will be seen that the door has a rubber beading round its edges and a strong lever handle which forces the door tightly into its frame.

The cabinet is practically the same in principle with all types of refrigerators. The different types vary only in the method by which the cooling unit is made to operate. Actually there are four types of domestic refrigerators, although only two of them are automatic. These types are: water-cooled safes; ice boxes; compression-type refrigerators; absorption-type refrigerators.

There is one basic principle upon which all refrigerators operate. It is that when any liquid evaporates heat is absorbed. This phenomenon is met with in many ways in our daily life. If you run hard on a hot day and then take off your hat in a breeze, you will experience an icy sensation across your forehead. This is because the evaporation of perspiration absorbs heat rapidly from the skin and thus lowers the temperature. Chills are caught in a similar manner by standing about in wet clothes. Heat is abstracted from the body by the evaporation of the moisture in the clothes. In extreme cases wet clothes can become frozen stiff on a windy day in winter even though the temperature of the air may be well above freezing point.

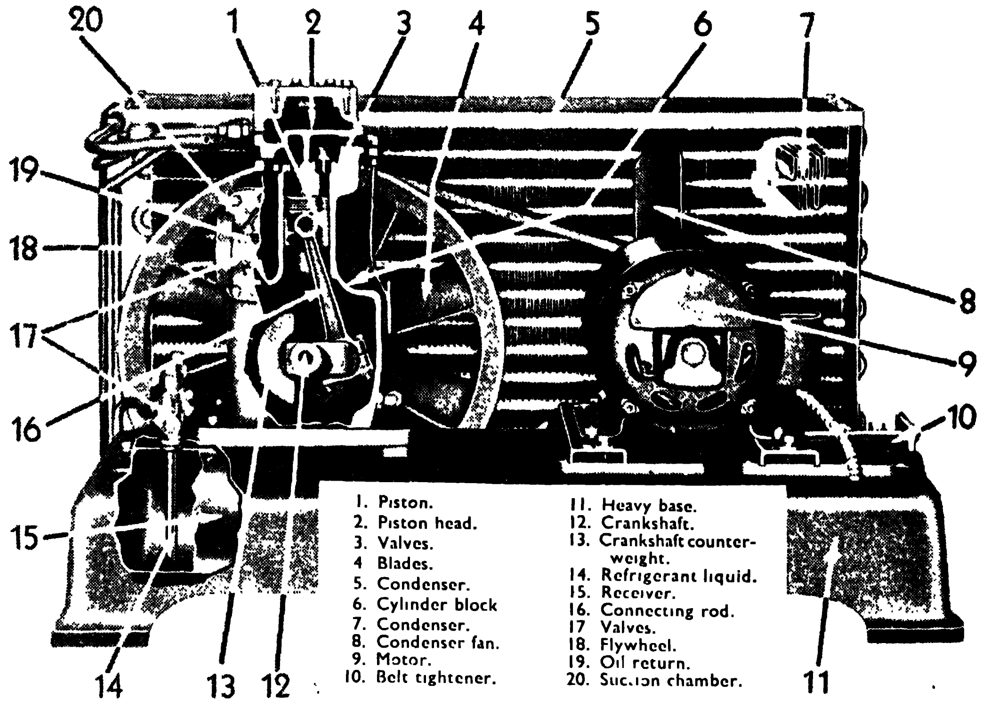


PRINCIPLE OF THE COMPRESSION TYPE OF REFRIGERATOR

Fig. 3. Practically all electrically operated refrigerators are of the compression type—that is, they operate by the alternate compression and expansion of a refrigerant. This is a gas, usually sulphur dioxide, which in evaporating absorbs heat. There are four main parts: a compressor, or pump-driven by electric motor; a condenser which cools the compressed gas; an expansion valve and an evaporator which is the cooling unit. The latter is inside the insulated cabinet, the other parts outside.

Bearing this in mind, let us now see how the various types of refrigerators work. First, there are water-cooled safes.

These are boxes with porous sides covered with material such as flannel, which will absorb moisture. This is kept wet by a water reservoir or by sprinkling and, as the water evaporates, the temperature inside the cabinet falls below that of the surrounding air. These safes work best if placed in a draughty place,

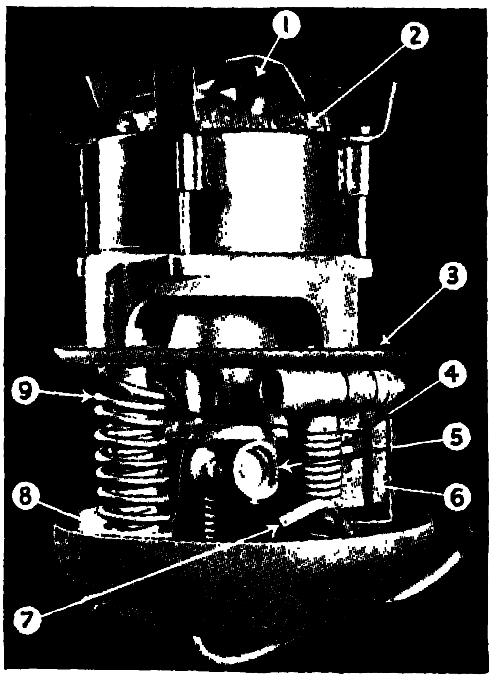


WORKING PARTS OF AN ELECTRICALLY OPERATED COMPRESSION TYPE REFRIGERATOR

Fig. 4. When we switch on the refrigerator the electric motor starts up and works the pump which compresses the refrigerant. The compressed gas passes in the direction of the arrow in Fig. 3 to the condenser and evaporator. Details of the mechanism are seen in the above diagram.

since the current of air will increase the rate of evaporation.

The ice box and ice refrigerator is simply composed of a cabinet which is heavily insulated and has for a cooling unit a container in which blocks of ice are put. As the ice melts, heat is absorbed from the air in the cabinet but fresh ice has to be added eventually when that which is already in has all



A REFRIGERATING UNIT

Fig. 5. This is a general view of the refrigerating unit of the compression type refrigerator. Parts shown are: 1, Motor cooling fan; 2, revolving part of motor; 3, condenser supporting plate; 4, springs to obviate vibration; 5, compressor; 6, valve plate containing compressor valves; 7, intake from evaporator through which the refrigerant is sucked; 8, oil sump; 9, refrigerant exhaust pipe coiled to prevent vibration. The gas formed in the evaporator is sucked into the compressor and the process is repeated automatically as long as the motor is running

melted. This type is only suitable where ample supplies of ice are available, as it is really second-hand.

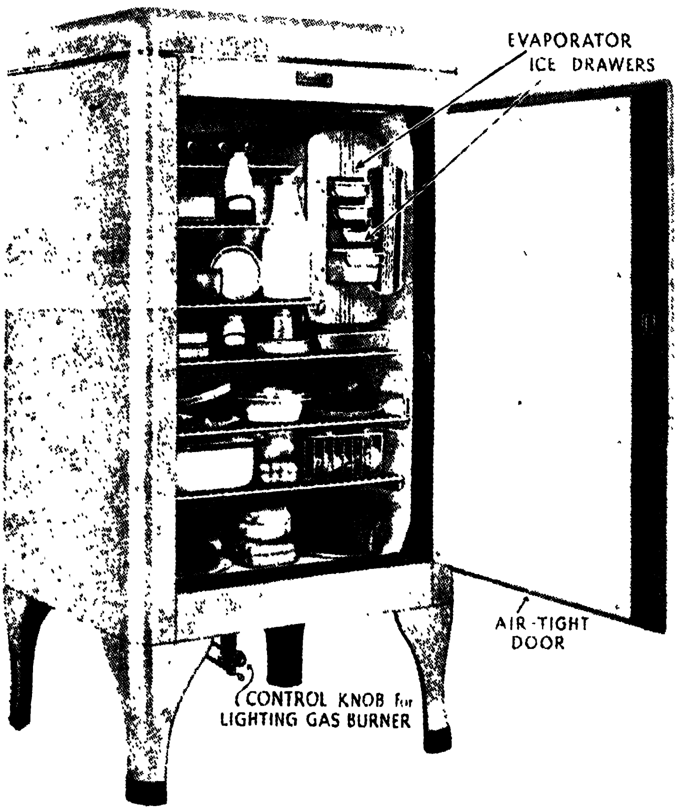
Practically all electrically operated refrigerators are of the compression type. In a sentence they operate by the alternate compression and expansion of a refrigerant. Now let us see what this means. There are several substances which exist as gases at ordinary atmospheric temperatures and pressures, but which, when compressed, become liquid. In order to compress such a gas, work has to be done by means of a pump, and some of this work is transformed into heat. This is found to be the case when pumping up a bicycle tyre—the pump and the tyre both become hot. If the bicycle were then taken into a cool place and the tyre allowed to cool and the valve suddenly removed, the air which rushed out would be very cold. This is because the reduction in pressure results in a reduction in the temperature.

EFFECT OF COMPRESSION

If we compress some gases sufficiently high and then cool them, they will liquefy. If we then expose this liquid to a lower pressure it will immediately evaporate, i.e., become a gas again, and, in so doing, will, as we have already seen, absorb heat from its surroundings.

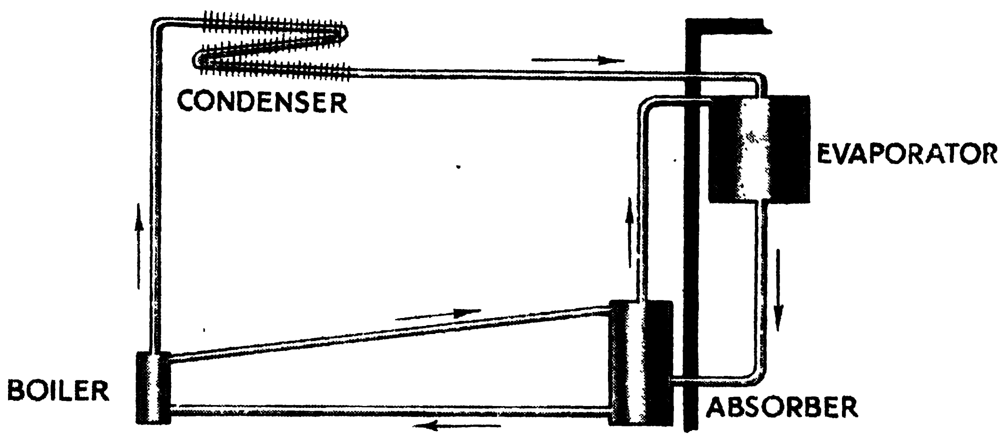
The arrangement of a compression-type refrigerator is shown in Fig. 3. It consists of four main parts: a compressor, which is really a pump driven by a small electric motor; a condenser, which is used for cooling the compressed gas; an expansion valve; the evaporator, which is the cooling unit and is placed inside the insulated cabinet. All the other parts are outside the cabinet.

The gas which is usually used, and which is known as the refrigerant, is sulphur dioxide. It is an evil-smelling gas, but that does not matter as it is in a completely hermetically sealed system outside the cabinet.



A GAS OPERATED REFRIGERATOR

Fig. 6. This type of refrigerator has no moving parts. The whole process is brought about by the application of heat, in the shape of a small gas flame. The refrigerant (ammonia) is dissolved in water from which it is driven off to the condenser. The principle is made clear by Fig. 7



HOW AN ABSORPTION TYPE OF REFRIGERATOR WORKS

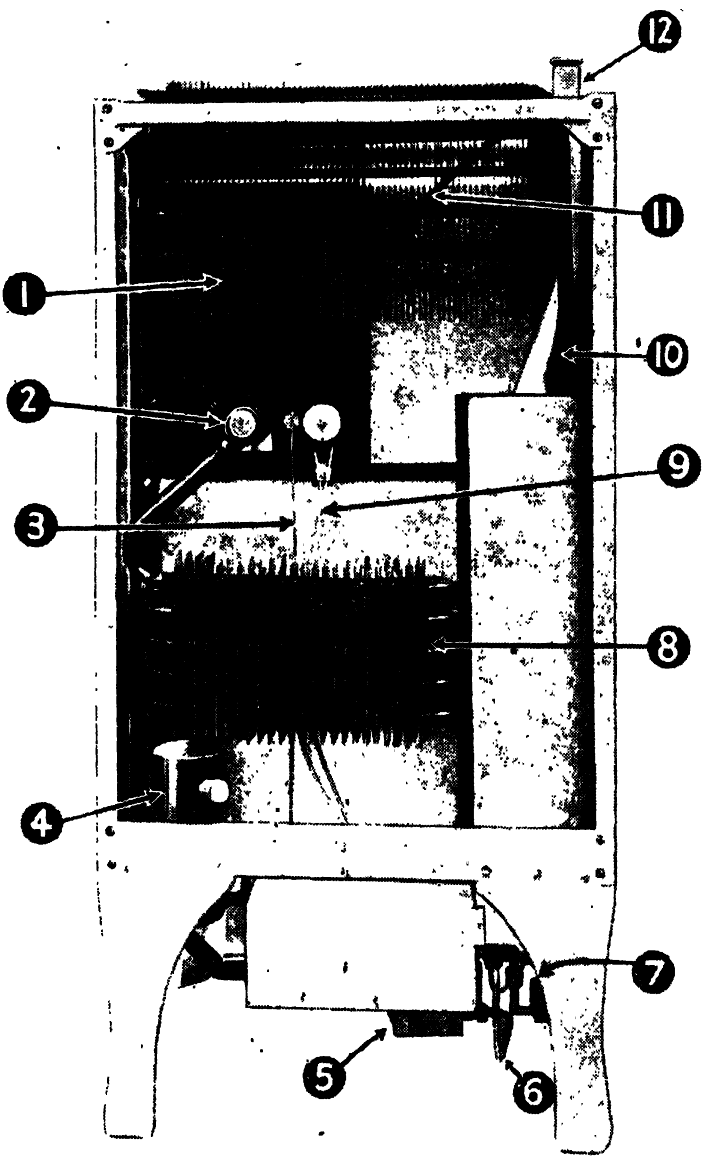
Fig. 7. A strong solution of ammonia gas in water is put in the boiler. On being heated by the burner the gas is driven off to the condenser where it is air cooled and becomes liquid. The liquid ammonia flows into the evaporator which is inside the cabinet and evaporates in the presence of hydrogen. In the absorber the ammonia is reabsorbed by water and flows back to the boiler while the liberated hydrogen returns to the evaporator. The same cycle of operations is then repeated.

Now let us follow the cycle of operations and see what happens. When we switch on the refrigerator the electric motor starts up and works the pump which compresses the refrigerant to a pressure of about four to five atmospheres (60 lb. to 75 lb. per sq. in.) (Fig. 4). The compressed gas, which is warm, now passes in the direction of the arrow (Fig. 3) until it reaches the condenser, which is a series of pipes with fins over which air can circulate. The gas now cools and becomes a liquid which is pushed along to a receiver and then to the expansion valve. This is a small hole on the outlet side of which is a large container—the evaporator. The pressure in the evaporator is much lower because the pump is sucking from it. Hence, as soon as the liquid passes through the expansion valve, it immediately evaporates in the evaporator and, in so doing, becomes very cold and absorbs heat from the interior of the cabinet. The gas thus formed is sucked into the compressor (Fig. 5). is recompressed, and the whole process thus continues automatically for as long as the motor is running. Actually, we need never switch the motor off as this is done for us automatically by means of a thermostatic switch. As soon as the cabinet reaches a sufficiently low temperature, a thermostat comes into operation and switches off the motor. If the cabinet temperature tends to rise the thermostat will switch the motor on.

ABSORPTION TYPE REFRIGERATORS

These are possibly the most ingenious form of refrigerator since they have no moving parts. The whole process is brought about by the application of heat, usually in the shape of a small gas flame (Fig. 6). At first glance it seems impossible that the heat from a gas flame should be made to produce cold.

One advantage of this method is that refrigeration can be obtained in remote places where gas or electricity are not available—such as in the desert. In place of gas a small oil burner can be used



ABSORPTION REFRIGERATOR FROM THE BACK

Fig. 8. The main parts of this ingenious type of refrigerator are: 1, Cooling fins; 2, connexions to evaporator; 3, thermostat control tube; 4, absorber vessel; 5, gas governor; 6, gas supply pipe; 7, gas burner; 8, absorber coils; 9, thermostat cable; 10, flue pipe; 11, condenser; 12, flue outlet. The principle is the same when an oil burner replaces gas.

The principle is the same in essence as that of the compression type, but there is, of course, no compressor, neither is there an expansion valve. In order to dispense with the compressor the refrigerant (which in this case is ammonia) is dissolved in water from which it is driven off under pressure by being boiled by the application of heat. The expansion valve is eliminated by allowing the liquid to evaporate in the presence of hydrogen gas.

The cycle of operations is seen in Fig. 7, and the principal parts in Fig. 8. The cycle is as follows :—A strong solution of ammonia gas in water is in the boiler. On being heated by the burner the ammonia gas is driven off to the condenser where it is air cooled. Here, owing to its high pressure of about eight atmospheres (120 lb. per sq. in.), it becomes liquid. The liquid ammonia now flows into the evaporator which is inside the cabinet. In the evaporator, in the presence of hydrogen, the ammonia is able to evaporate and so absorb heat from the cabinet. A mixture of ammonia vapour and hydrogen flows into the absorber where it is separated. The cycle is then repeated.

HOW A LAUNDRY WASHES YOUR CLOTHES

The science of a laundry. Handling a week's wash. The marking machine. Expert classification. The washing machine. The hydro-extractor. Ironing machines. The twin press. The shirt unit. Hot-air drying. The bag-wash.

GLANCE at half a dozen appropriate advertisements and reflect how distastefully a woman looks forward to washing clothes at home, and how keen is the competition to lessen this task for her or even to relieve her of it entirely.

Only laundries can completely fill the bill in this respect, yet few give thought to the highly scientific level to which they have been raised. The research station at Hendon of the Institution of British Launderers is by no means a glorified laboratory; it includes, on the contrary, a working laundry and would-be launderers and laundry chemists approach their work as though they were already in harness. The modern laundry is being continually and cleverly developed. Much account must be taken of the structure of textiles· even more of the quite involved chemistry lesson which signals the union of reagents in soap with water and all its impurities. Thousands of shirts, socks and handkerchiefs, of sheets, curtains and all the motley of what we wear and the textiles with which our homes are furnished are dealt with speedily, regularly and well.

A typical week's wash—how is it handled? As soiled linen reaches a laundry it is put together into lots of from 35 to 120 parcels, or dealt with simply by weight, to suit in either case the capacity of the machines.

Although lots are made up at random as parcels arrive they show surprising uniformity; every lot of, say, 6 cwt. will contain nearly the same number of shirts, handkerchiefs or pyjamas, much the same proportion of white or coloured goods, woollens, and so on, approximately equal weights of flatwork (sheets, for example, or tablecloths), and equal amounts of personal and household linen.

As a first step the contents of each parcel are checked against the customer's list, which is often regrettably inaccurate, and the list is then priced.

CHECKING AND MARKING

Those busily checking are also responsible for laundry marking by various means. Precautions are naturally taken whereby no two customers have the same mark—no small achievement.

Marking is always made in easily found positions, near a corner on sheets and tablecloths, for example, or on shirts at the centre of the neckband. One method used is by hand sewing in coloured cotton, and great skill and speed are shown in the freehand stitching.

Machine-finished laundering led to an increased use of marking ink, which is inexpensive, but sometimes unsightly, and mistakes, moreover, cannot be remedied without difficulty.

An advantage over handwritten marking is scored by a marking machine (Fig. 1) in which any combination of letters and figures is composed with the

USING THE MARKING MACHINE

Fig. 1. An advantage over handwritten marking is scored by the marking machine in which any combination of letters and figures is composed with the aid of an arrangement of levers rather like a railway signal box in miniature. Once a mark is registered, stampings can be repeated.

aid of an arrangement of levers rather remindful of a railway signal box in miniature. Once a mark is registered, any number of stampings can quickly be made in the fashion seen above.

Sewing machines which automatically run round the four edges of a short length of marked tape are used by some laundries, but the method is costly and not to be expected in other than the higher-priced services. Another adapted sewing machine stitches letters and figures directly on the article being marked, a simple set of stencils ruling the operation.

Some methods involve no actual marking of the linen. A small metal clip may be attached, for example; or small items, such as handkerchiefs may be placed in distinctive bags made of netting, which accompany them unopened during the actual washing.

Marking may even be done with invisible ink, which can only be seen in the rays of a special lamp.

After being marked articles pass—generally along a moving conveyor belt—to a set of classification bins, in which they rub shoulders as it were, according to the way in which they will be washed.

CLASSIFICATION

Table linen, for example, is washed separately from bed linen, and coloured and white goods are treated differently from each other. Woollens and other delicate fabrics are dealt with specially. Classification is the work of experts. They must be able to recognize, amongst other things, fugitive colours which might run and discolour a whole machine load of linen.

This careful determining of the right treatment for each type of textile is in marked contrast as between the work of a laundry and that of many women who wash clothes at home. In the wash-tub every article goes through a similar routine. The quantities of soap and water per article, the duration of the treatment, the temperature of washing and rinsing waters, and the amount of rubbing may be left to chance and may vary from week to week. But in the laundry wash-house (Fig. 3) the various factors are carefully controlled.

THE WASHING MACHINE

Washing is done in a washing machine (Fig. 4), which has a large hollow cylinder rotating slowly backwards and forwards. Inside this are three lifts which gently circulate clothes through the water—a process much less wearing than what goes on in a domestic wash-tub. The surface of cylinder and of lifts is made specially smooth, with rounded edges, to prevent damage to the linen. The linen remains in the machine

throughout the process, the various waters being changed as required.

An example of ingenious wash-house methods is afforded by a machine set aside for washing sheets. This machine has a standard load, that is, weight of sheets to be washed each time. In most up-to-date laundries checking and classification is done on a gallery above the wash-house, classification bins being large galvanized-iron containers with a trap-door bottom (Fig. 2). Through this a fixed number of sheets falls through.

When the sheets are in the washing machine the first change of water is flushed in. This is generally a soak, and it is followed by a cold wash, warm wash, hot wash, hot rinse, warm rinse, and cold rinse. In each case there is a fixed time of running, a fixed depth of water at a fixed temperature, and fixed quantities of liquid soap and other additions. The whole sequence of washes and rinses takes about an hour.

There is a small amount of hand washing of very soiled or fragile articles.

THE HYDRO-EXTRACTOR

The clothes now pass to what is perhaps the most interesting of all the machines in the laundry—the hydro-extractor (Fig. 5), in which the greater part of the moisture is extracted from the clothes without wringing. The hydro consists of two cylinders, one within the other, the inner one being perforated (Fig. 6). The clothes are loaded into it, the lid is closed, and the inner basket is then set revolving at a very high speed. The water is thrown out of the clothes and through the perforations by centrifugal force, and runs to waste.

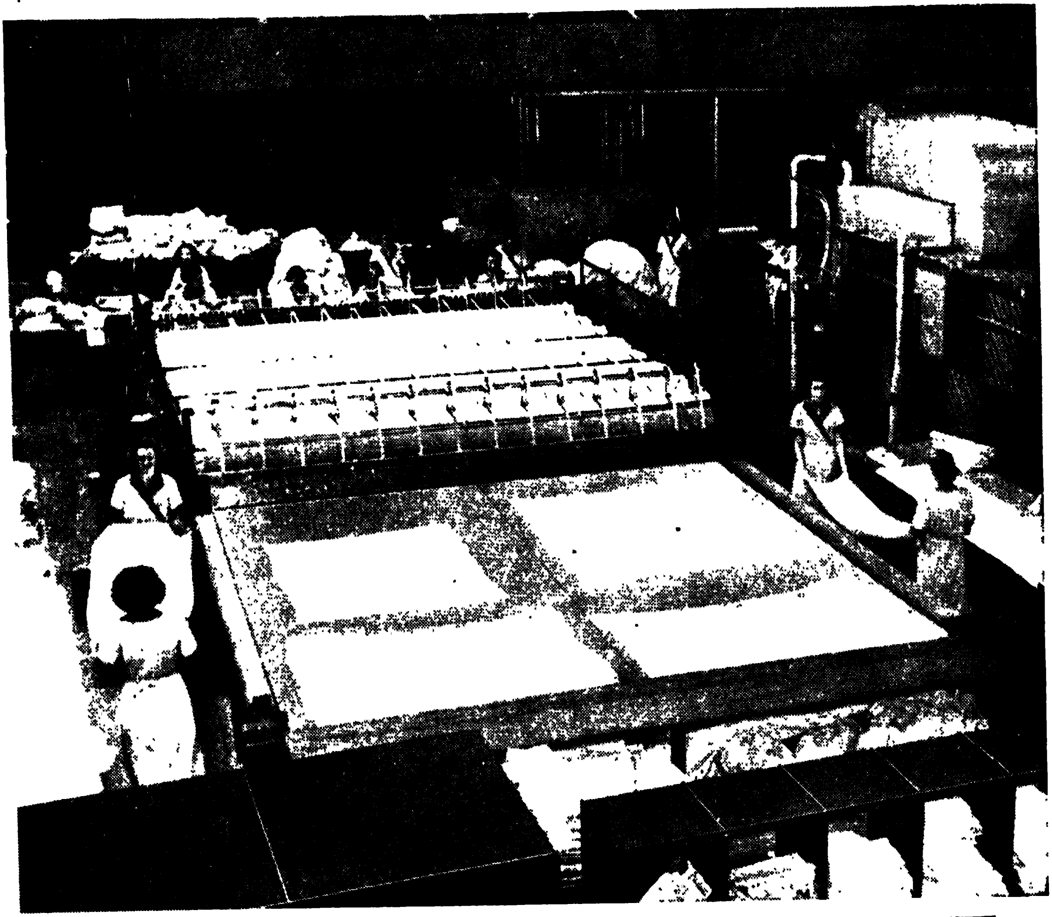
We now come to the many and varied ironing processes for which a host of ingenious machines has been devised, even for different parts of the same article. Even so, the homely flat-iron has by no means been ousted from laundries (Fig. 7); it is widely used for topping-up—finishing off—machine-ironed articles, and for personal linen in the dearer services where special care is needed.

Some laundries use special gas-irons, with the flames inside the iron. A constant temperature is maintained.

It is large flat work, such as sheets and tablecloths, which presents the greatest difficulty in ironing at home, but in modern laundries such work is dealt with easily and quickly. The multi-roll flat-work ironer is the largest and most expensive machine used in laundries (Fig. 8). It consists of four, six, or eight hollow steel rollers, which are kept filled with steam at pressure. These run on a steel bed similarly heated A

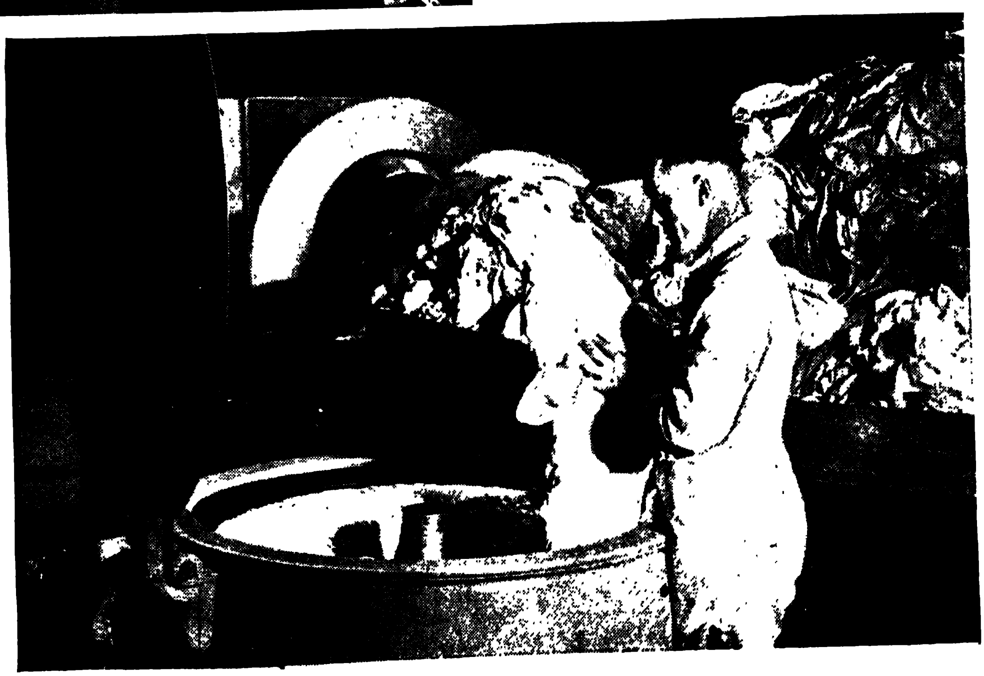
CHECKING AND CLASSIFYING

Fig. 2. Checking and classification in most up-to-date laundries is done in a gallery above the wash-house. Classification bins are large galvanized-iron containers of the type shown here. They have a trap door, sometimes controlled by a counterweight, so that the bottom open under a given pressure of the contents



LAUNDRY IN ACTION

Figs. 3, 4 and 5. At left is a general view of the large hall (photographed by courtesy of Collars Ltd.), where all the operations of washing clothes take place. In the background are the washing machines and the hydro-extractors which remove moisture from the clothes. In the foreground are multi-roll ironers where large flat work, such as sheets and tablecloths, is dealt with. The procedure is as follows: After being marked, the articles to be washed pass to the classification bins (seen in Fig. 2) and thence to the washing machines. These have a hollow rotating cylinder in which the clothes are circulated with various changes of water. In Fig. 4 (below, left) clothes are being loaded into one such machine. The next stage is the abstraction of moisture without wringing, by means of the hydro-extractor. The clothes are loaded into this machine which contains a perforated cylinder revolving at high speed, the water being thrown out of the clothes through the perforations. In Fig. 5 (below) a "cheese" or heap of moisture-free clothes is being removed from the hydro-extractor. Ironing is the next stage, and the rollers are fed with a stream of articles by the laundry girls, who also lift and fold each article as it comes from the machine. Pressing is a following stage and the presses used are also to be seen (right), in our general view of the laundry. Twin presses are often used, so that while one article is being steamed the operator can, at the same time, place another article in the second press. When articles are finished they move to a racking department, where they are sorted into racks bearing the laundry marks of the various customers concerned



continuous sheet runs round the rollers, and carries the work on it. Before linen can be dealt with it has to be prepared by stretching it and folding it widthwise, with one edge exposed for feeding to the machine. This edge is held by two girls, one at each corner, who slip it on to the machine sheeting and under the finger guard, so that the sheeting carries it between the bed and the first roller (Fig. 9)—work demanding care and dexterity. It is essential to pull the feeding edge tight as the article enters the machine, otherwise the edges will be concave when finished. The operators have to be quick in order to ensure that a second article follows hard upon the first, for waste space between the articles lowers the production rate. There is a guard to prevent the operators having their fingers caught. The largest multi-roll ironers are 160 in. wide, and two teams, each of two girls, feed it side by side. The speed of the moving band can be regulated, and, up to a point, the slower the speed the better the finish.

FINISHING

For still better finish, such as for good tablecloths, a smaller machine, consisting of four or two rollers, or even of a large single roller, is used, with the belt travelling far less quickly. This is, of course, much easier to feed. A tiny version of the single-roller machine is sometimes used for handkerchiefs, collars and so on, as illustrated in Fig. 10.

As flat work comes out of the machine it is taken off by teams of girls corresponding to the feeding teams (Fig. 8). These girls lift and fold each article in two or three quick movements.

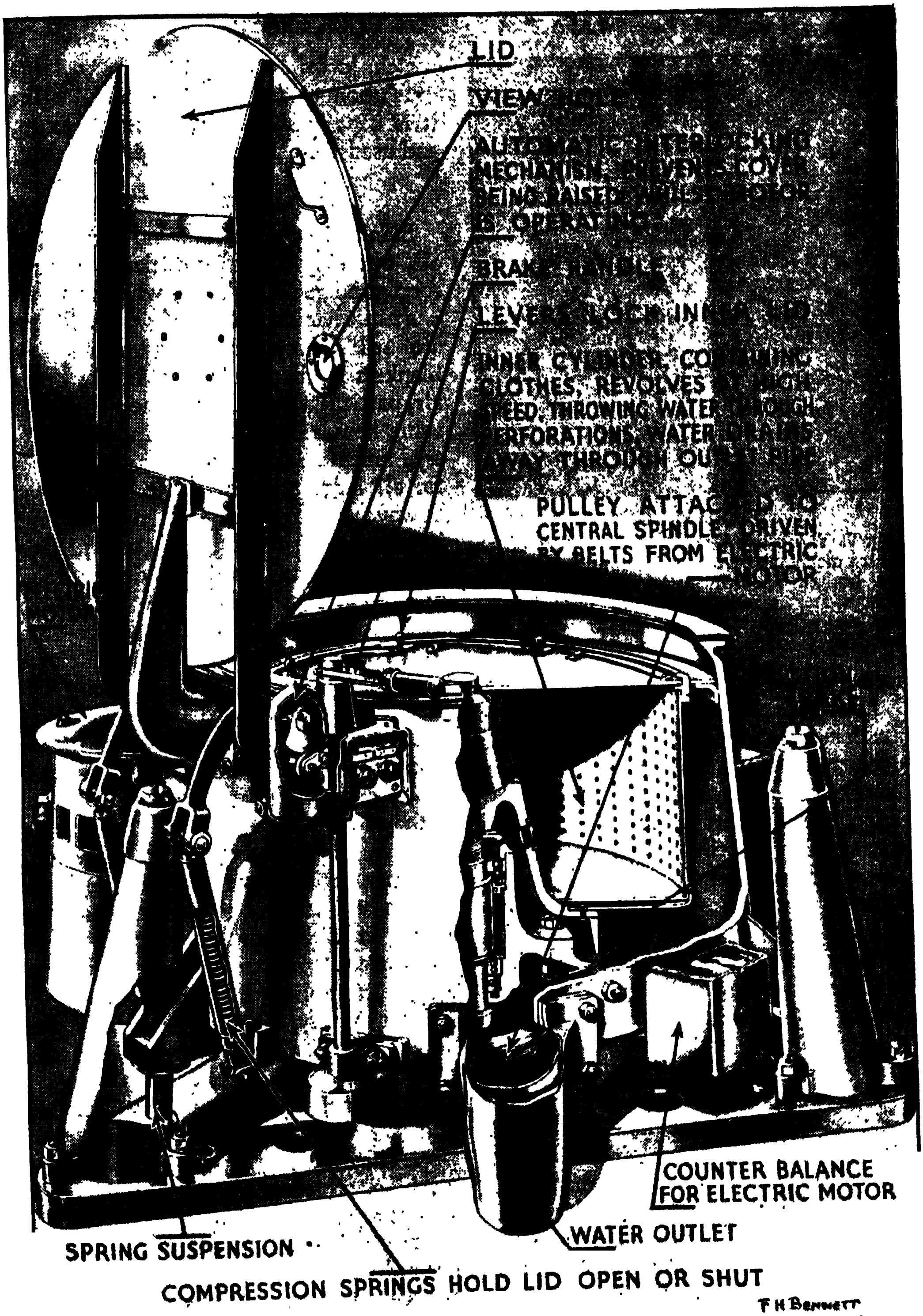
Presses of various kinds are also widely used. These are similar to the presses which are seen in dry cleaners' shops, with a padded head which clamps down on to a hollow bed filled with steam under pressure. The earliest presses had a handle on the head by which the operator pulled it down with one hand, but the girls sometimes caught the fingers of the other hand in the press, so newest models are designed in such a way that the head comes down automatically when two buttons, one on each side of the machine, are pressed, and this ensures that both operators' hands are safely out of the way when the press head comes down.

PRESSING

Some presses are flatter and much wider than those in the dry cleaners' shops, and are used for larger articles, such as boiler suits. With a press, after the head has come down, the operator has nothing to do for a few moments whilst she is waiting for the steam to pass through the article, so these presses are now often made in pairs, called twin presses (Fig. 11). The operator lays an article on one press and the head comes down, and while the article is being steamed she puts another article in the second press. By the time the head of this press comes down, the head of the first press is ready to come up again, and in this way she passes from one to the other doing twice the work which could be done on a single press.

THE SHIRT UNIT

A special set of presses, manned by a team of two or three girls, is used for shirts (Fig. 12). This shirt unit, as it is called, results from careful study of ironing methods, and it can deal with shirts many times faster than they could be finished with a hand iron. In the shirt unit the body of the shirt is pressed first. The sleeves are then drawn over two hollow steam-filled sleeve shapes, and finally the front and cuffs are topped-up with a hand iron before the shirt is folded. There are special rails on which the shirts are hung as they are waiting



MACHINE WHICH DISPENSES WITH WRINGING—THE HYDRO-EXTRACTOR

Fig. 6. The cylinder revolves at high speed and the water is thrown through the perforations

"TOPPING-UP"

Fig. 7. There are many ironing processes for which machines have been devised, but even so the homely flat-iron has by no means been ousted and is widely used for topping-up—finishing off—machine-ironed articles and for articles of value which require special care.

to be passed on from one to the next.

Laundries do not pin shirts up as much as they used to; at most, one pin is used, and sometimes not even that. Some laundries put a paper band round the shirt, some insert a board under the front to keep it stiff, and some put a tab through the cuff-holes.

In all presses both the head and the bed are thickly padded in an attempt to avoid damage to fragile buttons, but only hand ironing will altogether avoid some danger of damage in this respect.

METHODS OF IRONING

The two shapes used in the shirt unit for sleeves represent a new method of ironing—that is, by stretching the article over a heated surface. This method is now used for many other articles, such as socks, and it is particularly valuable for finishing artificial silk. Every woman knows what a problem this material represents, for if an iron is left on it even for a moment it begins to melt. A special hollow shape called a buffer—which looks rather like a very large mushroom—is used for artificial silk: it is kept at a fairly high temperature, and used very lightly and very quickly.

DRYING BLANKETS

Blankets, of course, are not pressed at all, but they are very difficult to dry, for a good quality blanket when wet will contain several pounds of water. There are still many laundries which dry blankets by hanging them in the open air, particularly in the summer—indeed, some laundries, especially in the country, make a feature of open-air drying for all large articles. Some launderers, however, are opposed to open-air drying in any circumstances, and contend that it is unhygienic to leave damp linen exposed to dust in the atmosphere, even in the country and even on a fine day.

These launderers dry their blankets in a hot-air chamber. In these the blankets are suspended from hooks on a slow-moving conveyor belt which slopes up and down through the chamber and emerges with the blankets quite dry. If they have been well rinsed before this process, they dry very soft to the touch.

Other articles not pressed are bath towels and turkish towels. These are dried in a hot-air tumbler, a large cylindrical wire cage which revolves slowly, tumbling the articles about. A current of hot air passes through the machine, and after a few moments the towels are dry and soft.

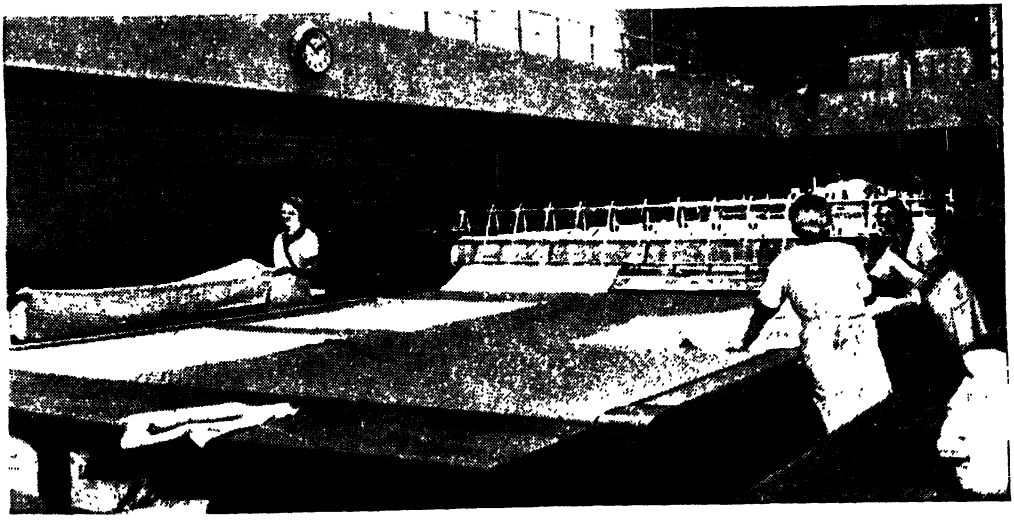
Starched articles, such as stiff collars and dress shirts, need very careful ironing. They are laid on the flat bed of a machine, which is passed to and fro so that heat and pressure are gently applied to the articles. A little moisture has to be applied from time to time to keep the surface consistent. A special curling and finishing machine, by which a jet of steam softens the starch, enables collars to be dealt with rapidly (Fig. 13).

Fancy and frilled articles are ironed by hand. The hand ironers, unlike most of the other staff of the ironing room, are not paid on piecework or bonus rates, for they are encouraged to take their time over this delicate work.

When articles are finished they move towards the racking department. Here a number of large racks (Fig. 14) made of either wood or steel, are marked with the laundry marks of all customers whose parcels are in that particular lot. When the parcel is a large one, it may have one compartment of the rack to itself, but sometimes the compartment is shared between two or three smaller parcels. Girls pass with armfuls of linen along the line of these racks, putting each article into its proper place with the book or ticket or list for that parcel. Gradually each customer's articles are assembled together—the flat work underneath, then the larger personal linen, and finally smaller things like handkerchiefs and collars. Sometimes there are one or two laggard articles which come in some time after the rest—perhaps a particularly soiled article such as a pair of workman's overalls which has had to be rewashed, or a particularly delicate one which has taken a long time to iron, or one which has been left behind when a washing machine or hydro-extractor has been emptied, or one which has slipped by accident into the wrong lot.

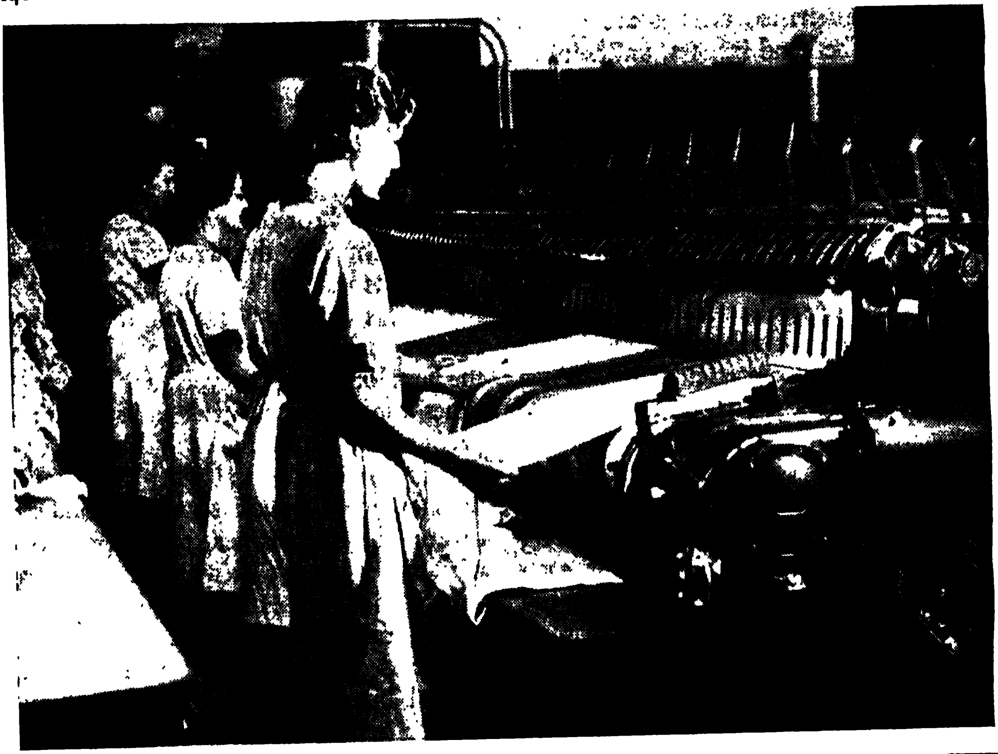
But when the bulk of the lot is racked, the packers get to work on it and the rackers chalk up a fresh set of marks for the next lot and begin work on it. Sometimes the racks are made of steel and pivot round on their base. The rackers work on one side, and when they have finished a lot the rack is swung round so that all the linen is next to the packers, who begin to pack it, whilst there is an empty side for the rackers to start using for the next set of articles.

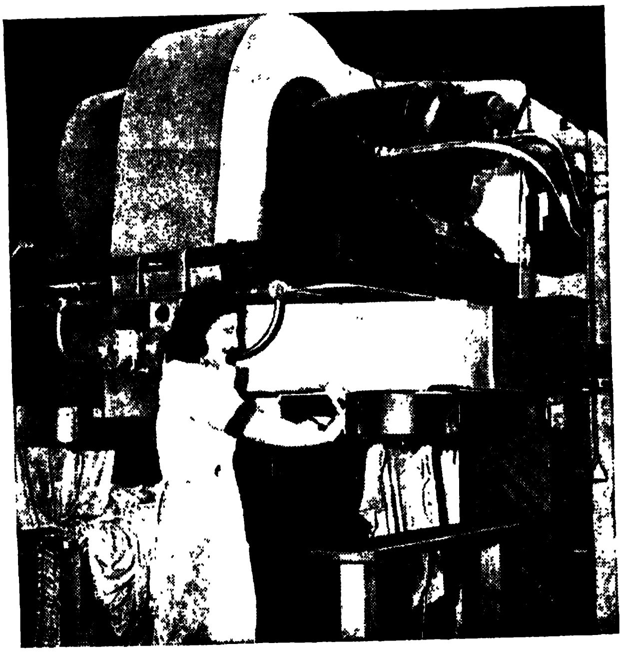
Parcels which are not complete are packed but left open until the article appears, as it usually does. If, however, it has not reached the packer by the time the vanman is ready to take that parcel out the ticket is marked "one so-and-so to follow," and the parcel is packed up



FOLDING SHEETS AT AN EIGHT-ROLL IRONER

Fig. 8. In the modern laundry large flat work, such as sheets and tablecloths, is dealt with easily and quickly. The multi-roll flat-work ironer is the largest and most expensive machine used. The hollow steel rollers are filled with steam and run on a steel bed similarly heated. A continuous sheet runs round the rollers and carries the work along. It is then quickly lifted and folded





HOW IRONING, PRESSING

Figs. 9, 10, 11, 12 and 13. Fig. 9, top, left, shows how the laundry girls slip linen on the machine heeting and under the finger guard. The operators need to be quick in order to ensure that a second article follows hard on the first. For superior finish a machine consisting of four or two rollers or even a large single roller is used, with the belt travelling less quickly. A version of this machine is used for handkerchiefs or collars as seen in Fig. 10 top, right. A twin press is shown in

AND DRYING ARE DONE

Fig. 11, bottom, left. The operator lays an article on one press and the head comes down. While the article is being steamed she puts another in the second press. A special set of presses called a shirt unit is shown in Fig. 12, bottom, centre. A special finishing machine by which a jet of steam softens the starch enables collars to be swiftly dealt with and is seen in Fig. 13, bottom, right. These ingenious machines do most of the work, though fancy articles are still ironed by hand.

and sent out. In the majority of cases the article appears over the weekend or by the following week, and the number of cases in which an article cannot be returned to the customer is, in most laundries, less than one in ten thousand.

When all the parcels are packed they are stacked and loaded into the van in reverse running order, so that they are in correct order as the vanman proceeds along his route.

A generation or so ago only well-to-do people sent large hampers of linen to the laundry, and most people sent only starched and frilly articles which they found difficult to wash at home. But the introduction of modern machinery, particularly multi-roll ironers and twin presses, enabled laundry prices to be cut by more than half, and this led to the growth of semi-finished, or more correctly machine-finished services, which tempted people to send more of their linen to the laundry.

In recent years, however, there has been a development which enabled wash-tubs and scrubbing boards to be banished from working-class homes as well. This is the bag-wash, or damp-wash service, and gets its first name from the fact that the laundry provides a large linen bag, of the same shape as a kit-bag, for each customer. In this is put as much as it will hold for there is generally a standard charge up to say 28 lb. weight. Only articles which can be boiled may be included, not those with fugitive colours, nor woollen goods.

The usual charge for this service is so small that the cost of washing a shirt is little more than a halfpenny, and of a handkerchief a fraction of a farthing.

ASSEMBLING THE FINISHED LAUNDRY IN THE RACKING DEPARTMENT

Fig. 14. The racks of wood or steel are marked with the laundry marks of all the customers whose parcels are in one particular lot. When the parcel is a large one it may have one compartment of the rack to itself, though sometimes the compartments are shared. Girls pass with armfuls of linen along the line of these racks, putting each article in place and gradually the customer's articles are assembled—flat work underneath, then the larger personal linen, with the small things on the top

HOW A VACUUM CLEANER SWEEPS YOUR ROOMS

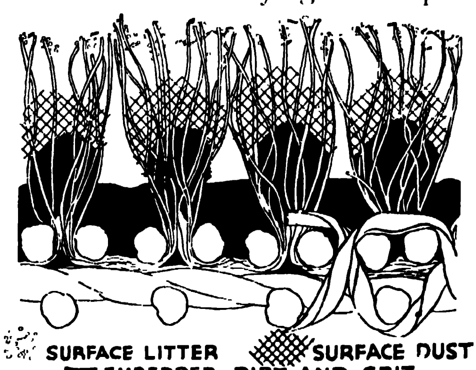
The principle of vacuum cleaning. The types of cleaner—cylinder, bag-and-handle, simple suction, mechanical brush and vibrator. The motor-driven agitator brush. Accessories.

Dust and dirt in our homes—persistent foes, no sooner banished in part than they begin to accumulate again—dust brought in by the air, pollen, coal dust, soot, dirt trodden into carpets, fluff from bedclothes, feathers, cobwebs, moths' eggs, germs! The parrying of their insidious thrusts day after day with broom, brush and duster, the shaking of rugs, the upheavals of spring cleaning—what variations and repetitions of backaching tedium may be enforced! Moreover, much of the disturbed dust mostly floats about in the air nearby for a brief time and then resettles itself—on food maybe—when it would better have remained on furniture or floor.

What is brought in by the air, and far more besides, can be removed by air: that was the thought that must have given birth to the idea of the vacuum cleaner, one of the greatest labour-saving devices, in the aggregate, ever conceived.

Few people realize that it is the higher pressure of the air outside the vacuum cleaner, and not the reduced pressure within, that does all the work, the vacuum cleaner having merely adopted for its own purposes, a sort of atmospheric defencelessness in the region of its hungry jaws so that a brisk current of air is allowed to push its way actively in, bearing small foreign bodies helplessly before it.

There is, of course, no such thing as a perfect vacuum, though that induced, for example, at the top of the tube of the mercury type of barometer is of a high order. Here a heavy 30-in. column of mercury may be supported in a tube, but again it is *not* the vacuum which exerts some mysterious, indeed impossible, tension to maintain the column, but the pressure exerted at the base of the latter by atmospheric pressure outside. The partial vacuum set up at the nozzle of a serviceable vacuum cleaner, though adequate, is of a far lower order, being continually reduced by incoming air. In case the foregoing remarks may suggest to some a means of trying out the paces



TYPES OF DIRT CLASSIFIED IN A CROSS SECTION OF SOILED CARPET

WHY A DIRT-REMOVING MACHINE IS NEEDED

Fig. 1. The modern type of vacuum cleaner is so constructed as to deal with each type of dirt contained in a carpet. Not only is it a more hygienic method of removing surface dust and litter than the sweeping by hand brush, but it drives out grit embedded at the base of the pile and otherwise beyond the reach of a hand brush.

of a vacuum cleaner, a warning is added that the delicate sensibilities of most types of barometer should not be subjected to air pressures lower than the lowest they might normally be called upon to indicate, though an aircraft altimeter—essentially an aneroid barometer designed to respond to very low pressures—would suffer no damage.

Vacuum cleaners have obvious advantages. For one thing, the expenditure of physical energy otherwise required for household cleaning is largely replaced by mechanical energy derived from electrical energy. Carpets, rugs and other fabrics to be cleaned do not have to be taken from the positions they normally occupy. Dust is not merely disturbed only to resettle to some extent, but collected in an easily disposable mass. Bacteriological tests on airborne dust in buildings prove that it acts as a carrier of germs; vacuum cleaning obviates this. Dust which cannot even be reached by a brush, in the pores of carpets, for example, can be easily driven out, even though embedded as in Fig. 1.

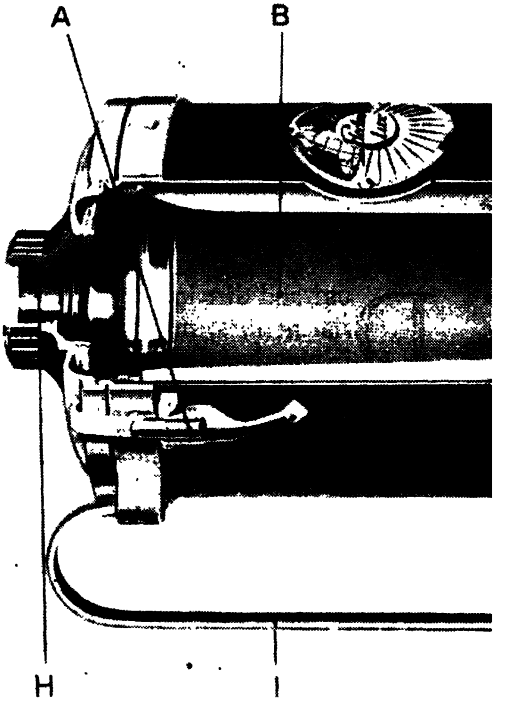
Reduced to essentials the function of a vacuum cleaner is to induce along an enclosed channel or channels strong currents of air from which are filtered suspended small particles of solid matter.

In some large buildings vacuum facilities are laid on, as it were, like water or gas, and it is possible to plug in at convenient points, and, with no nearby apparatus other than a nozzle and a length of flexible tube, to carry out the normal operation of vacuum cleaning. With such a plant the dust collected may be disposed of automatically into the sewage system.

Sometimes vacuum cleaning on a large scale is carried out by vacuum servicing companies who take to the scenes of their activities massive plants mounted on motor vehicles which in due course are connected by long, flexible tubes to suitable nozzles operated within.

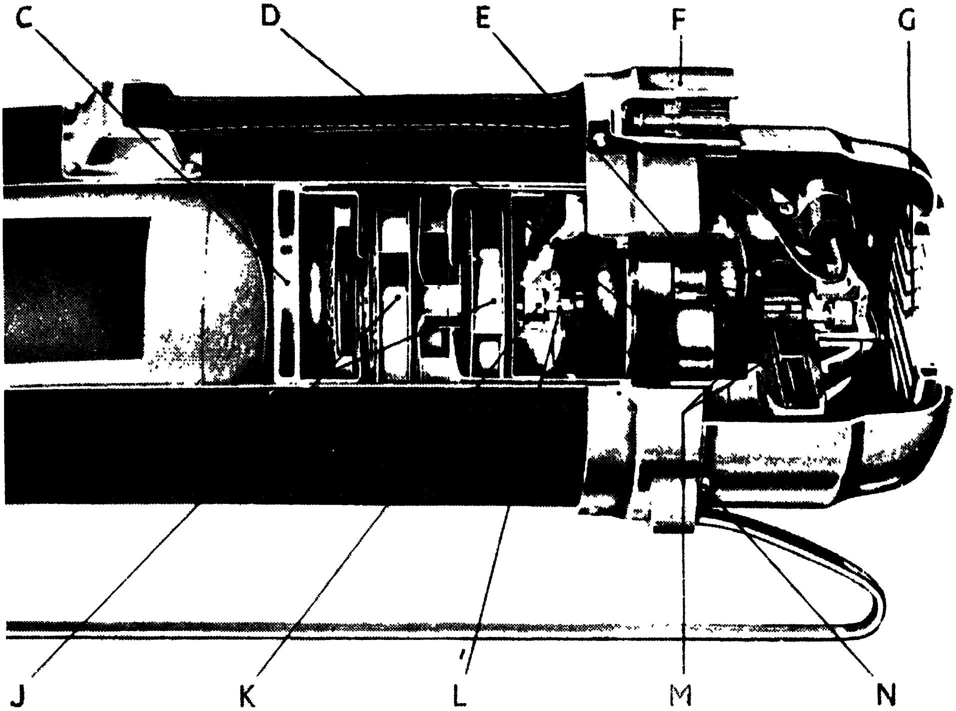
Perhaps rather strangely, the elaborate installation in buildings already referred to of vacuum cleaning, plug-in plants, was the forerunner and not the descendant of the simpler domestic types, which in some cases may not even be power-driven. These developed later.

The domestic vacuum cleaner consists essentially of an exhaust fan, a nozzle connected via an exhaust chamber with it, and a cloth bag by means of which dust is filtered from the escaping air.



THE WORKING

Fig. 2. In the cylinder type cleaner, the motor, fan and filter are all enclosed within a cylindrical case which is supported on runners. The cleaning is done by suction through a narrow nozzle, connected to the cylinder by a flexible tube. The parts shown above are: A, Catch to

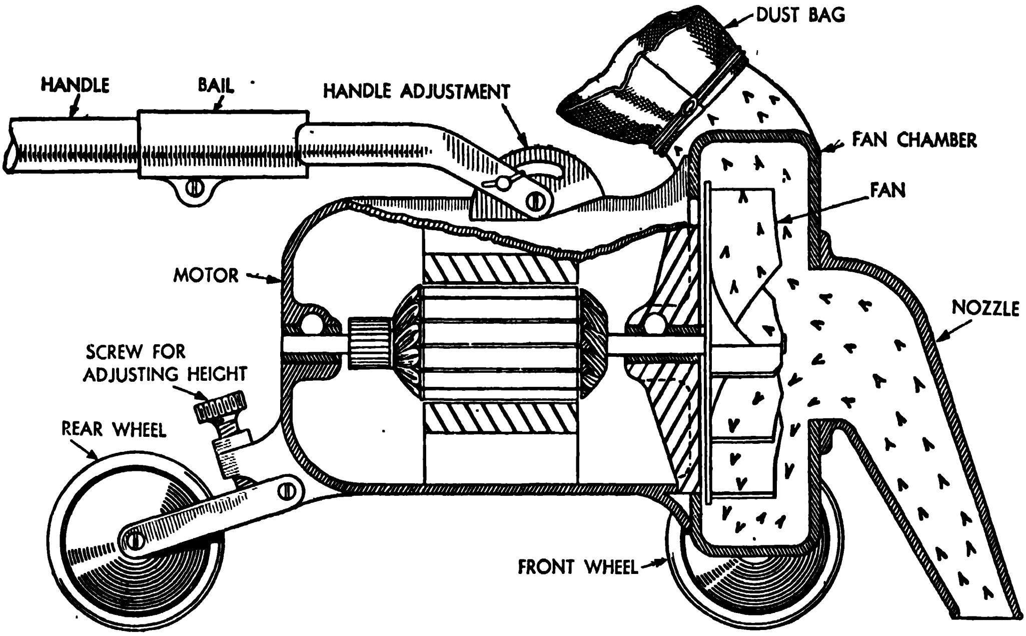


PARTS OF A CYLINDRICAL TYPE SUCTION CLEANER
release dust bag for emptying; B, hygienic bag, enclosed in metal body; C, changeable filter pad, eliminating bacteria from exhaust; D, resilient mounting, silencing operation of motor; E, insulation of live parts to avoid shock; F, special grounding arrangement; G, outlet for exhaust air; H, revolving socket for securing hose; I, metal sleighs to provide smooth running; J, motor-driven fan; K, double ball bearings; L, rotor spindle by which fan is revolved; M, undercut commutator and special carbons; N, sealed protection against unauthorized use. The dirt is disturbed as with a brush.

Occasionally the floor wheels of the vacuum cleaner itself, by a suitable system of slip-ratchet gearing in combination with a fly-wheel, cause the exhaust fan to rotate with sufficient activity to produce a reasonable result, and in remote country districts, where electricity has not yet been laid on, the type indicated is the only practicable one.

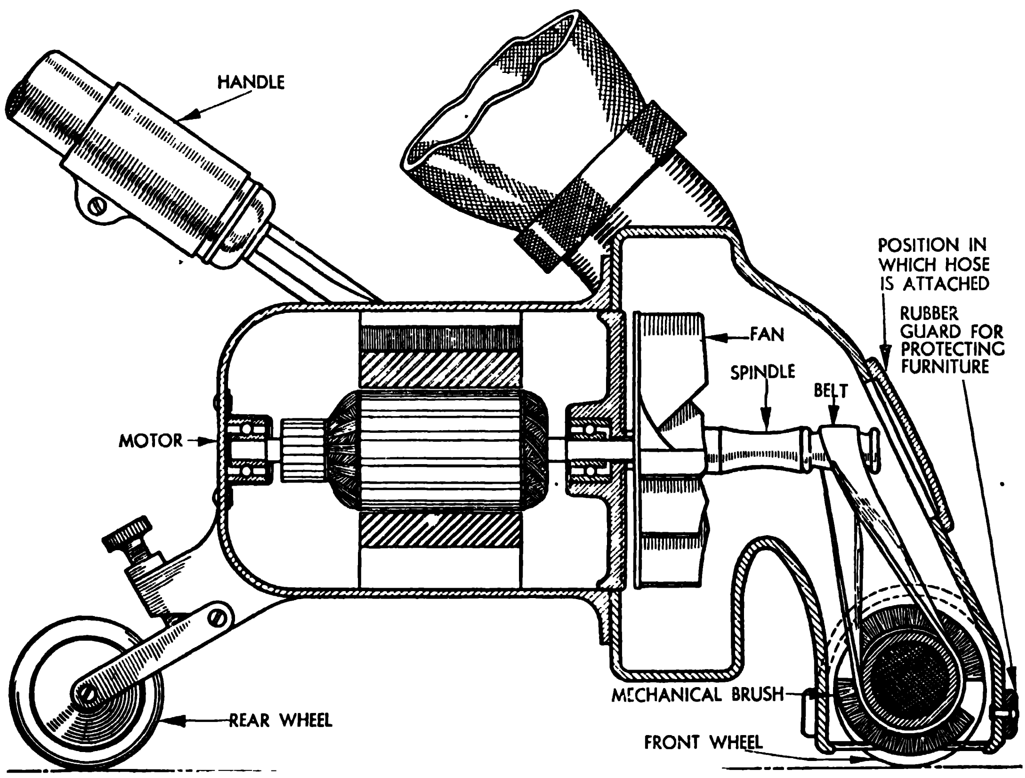
In most types of portable cleaners, however, an electric motor is incorporated to rotate the exhaust fan, and various other elaborations are taken advantage of. While the simple process of suction can deal unaided with surface dust, something equivalent to shaking, brushing or beating is necessary to disturb the dirt embedded, for example, at the bottom of the pile of carpets, and inventors have incorporated sweeping and vibrating appliances with many modern types of vacuum cleaners.

Portable domestic cleaners are of two main kinds—the cylinder type and the bag-and-handle type, the latter including three other main divisions, namely the



THE BAG-AND-HANDLE TYPE SUCTION CLEANER

Fig. 3. In this type of cleaner the dust bag is not enclosed but is suspended from the handle. There is no tubing, and the dirt passes directly from the nozzle into the bag.



THE MOTOR-DRIVEN BRUSH TYPE

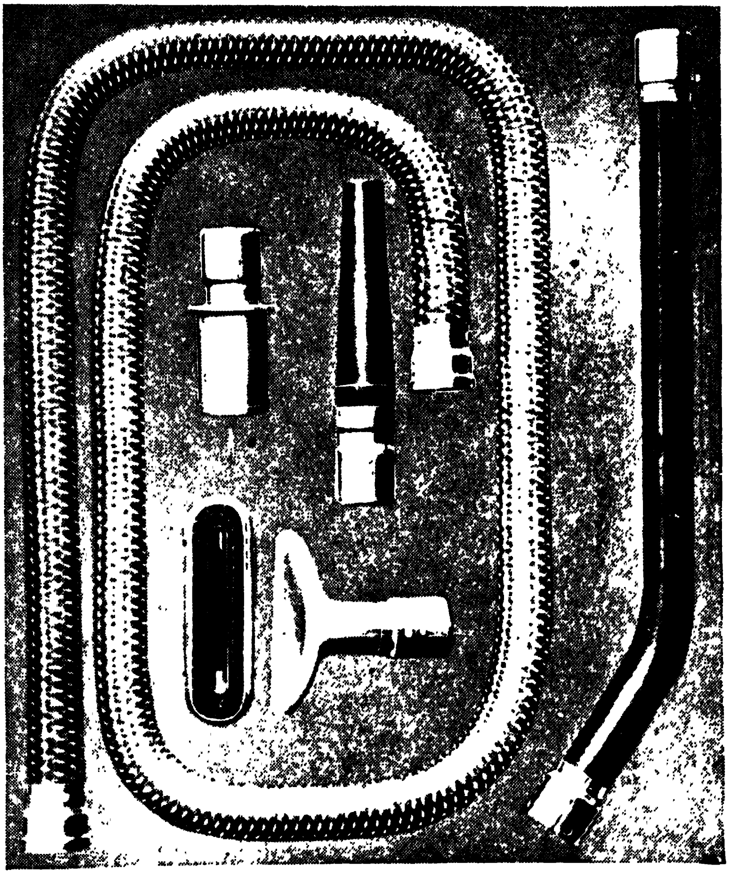
Fig. 4. An improvement on the straight suction cleaner is the motor-driven brush type, incorporating a rotating brush in the nozzle. The driving power is transmitted from the fan to the brush-roll

MOTOR-DRIVEN AGITATOR BRUSH

Fig. 5. A further improvement on the brush-roll is a rotating metal cylinder located in the nozzle. This cylinder is equipped with smooth metal bars in addition to a row of brush bristles

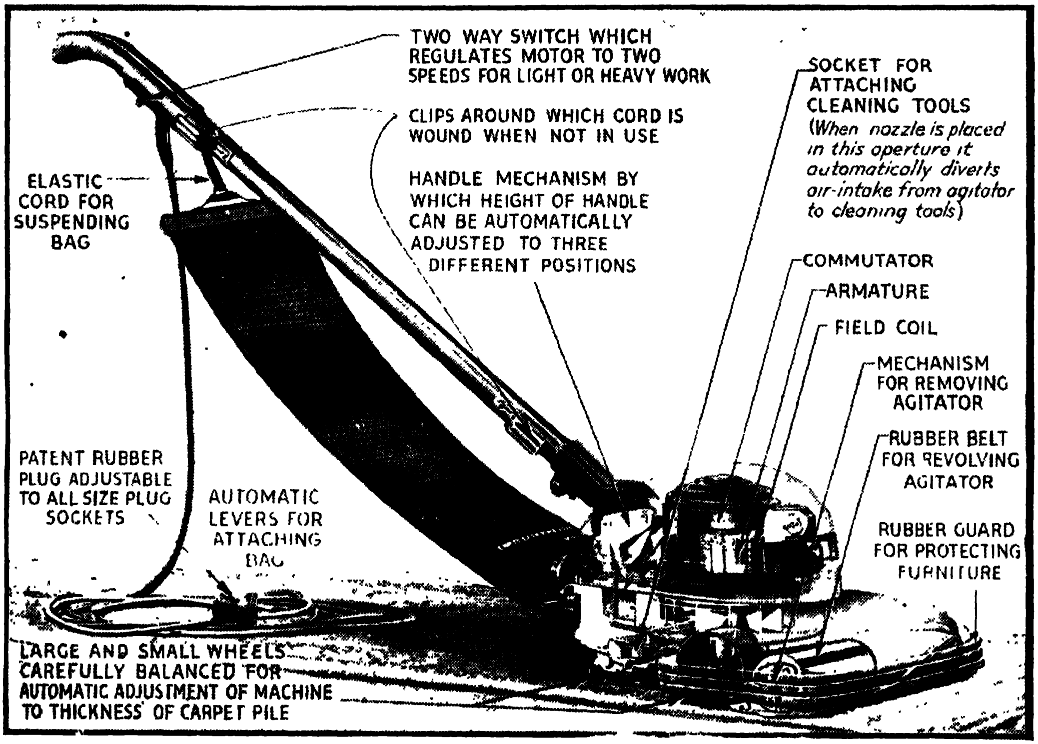
simple suction, the mechanical brush, and the vibrator. In the cylinder type (Fig. 2) the motor, the fan and the filter are all enclosed within a cylindrical case supported on runners and drawn over the floor as necessary. The cleaning is done by a narrow nozzle connected by a flexible tube with the cylinder. The nozzle is manipulated over the surface being cleaned, and the dirt passes through the tube into the cylinder. Various other attachments, including different types of brushes, take the place of the nozzle when required. The dirt is disturbed in exactly the same way as with a broom or brush, but needs no collecting in a dustpan.

The bag-and-handle type works on the same principle but has a handle conveniently situated for controlling the whole appliance, and the nozzle is at the base of the machine, just below the motor and fan. The filter bag is not enclosed in a cylinder, but is suspended from



CLEANING ATTACHMENTS AND THEIR USE

Fig. 6. This set of tools shows an extension for lengthening the handle at the right and enclosed in the additional length of hose is the adapter, by which the tools are attached to the cleaner, a brush for upholstery and curtains, an extra nozzle for "above the floor cleaning," and a flat nozzle for reaching into crevices and narrow apertures. Brushes are provided with a rubber guard to prevent harm to walls or furniture



PHANTOM VIEW OF A MOTOR-DRIVEN AGITATOR TYPE ELECTRIC CLEANER

Fig. 7. This diagram, adapted from a photograph and reproduced by courtesy of Hoover Ltd., exposes some of the main parts of the modern agitator cleaner. The nozzle which makes contact with the floor accommodates the brush-roll or agitator. The bars of the brush-roll beat the carpet and the rows of bristles sweep it. The revolving agitator is driven by a rubber belt. The fan beneath the motor causes air to flow through the carpet pile into the nozzle, dust being carried by suction through the fan chamber into the dust bag. Principal feature of the motor is the armature consisting of steel core and commutator through which the electrical connexion is made.

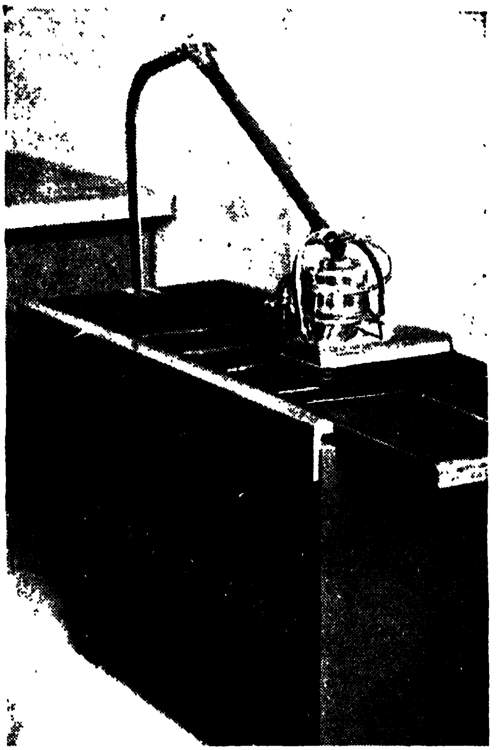
the handle, and has an inlet leading from the impeller. The whole appliance is moved backwards and forwards over the carpets and sucks up the dust into the bag directly, without its having to pass through a flexible tube (Fig. 3). This type, however, also usually includes dusting attachments (tubes, nozzles and brushes) similar to those of the cylinder type, but they are only used for cleaning such things as upholstered chairs, curtains, picture rails, tops of cupboards, the risers of stairs, and so on. One of the appliances usually consists of a long thin nozzle which can extract the dust from narrow crevices. The brushes may also be of different kinds—for delicate or rough furnishings, for example, and surrounding wide or narrow nozzles. They are attached to the cleaner by a director whose name explains its purpose.

Most types of vacuum cleaners can be reversed from suction to blowing by attaching the tube to the opposite end of the fan. This is useful for driving the dust out of otherwise inaccessible places.

Both types of vacuum cleaners so far described are known as simple-suction types, that is to say they rely upon hand manipulation to disturb the dirt in the same way as brooms and brushes.

Other types of the bag-and-handle vacuum cleaner employ mechanically revolved brushes which themselves disturb the dirt. At the present time there are many different kinds of mechanical-brush cleaners in constant use.

Invaluable as far as it went, the



THE BUMPING TEST
An electric cleaner is here undergoing one of the abuse tests by which resistance to wear is judged. It is moved to and fro on the mechanical operator over a series of steel bars, receiving no fewer than 160 impact jars per minute.

mechanical brush had for some time certain disadvantages which inventors tried to overcome. At last, after many experiments, it was discovered that if the carpet was lifted slightly by suction so that the pores of the carpet were opened, and smooth steel bars were incorporated with an improved brush vibrator (Fig. 5), the efficiency of the machine in removing dirt from carpets became almost perfect.

The most vital part of any vacuum cleaner is the motor, which is often completely enclosed to ensure that no dust shall enter or grease exude (Fig. 7). The motor is connected by flex to the source of electric current, either lighting or power, and is controlled by a convenient switch fixed on the machine itself.

Naturally the value of a cleaner justly depends upon the quality of its material and manufacture. For instance, only very high quality flex could stand the day-by-day winding and unwinding required, only a particularly stout and flexible rubber belt could provide adequately for the strain of connecting the mechanical brush with the motor spindle as it revolves at tremendous speed—almost 3,000 revolutions a minute in some machines. The material for the filter must be of exceptional manufacture to allow for its constant emptying, and yet to maintain its efficiency in allowing all the air and none of the dust to pass through it. Rigid tests are carried out.

WINDING TEST FOR ELECTRIC CORD
This machine determines the ability of electric cleaner cord to withstand wear and tear. The cords are wound and unwound on the handles, being tested six at a time. Cord failure is indicated by the electric clocks seen at the rear.

OVERHAULING TUBE TRAINS

Braking improvements in progress at the Acton depot of the London Passenger Transport Board.

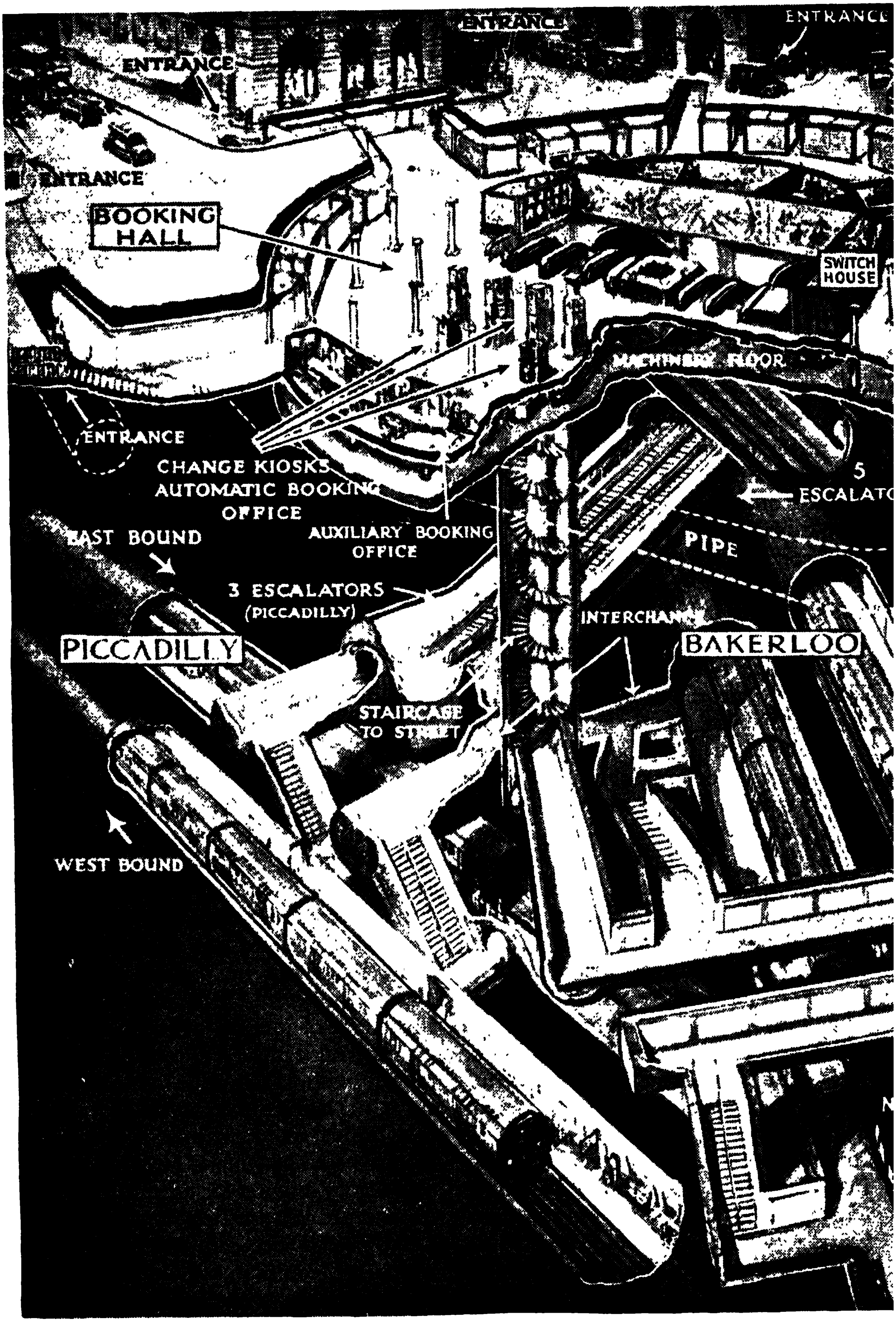
HOW A TUBE RAILWAY WORKS

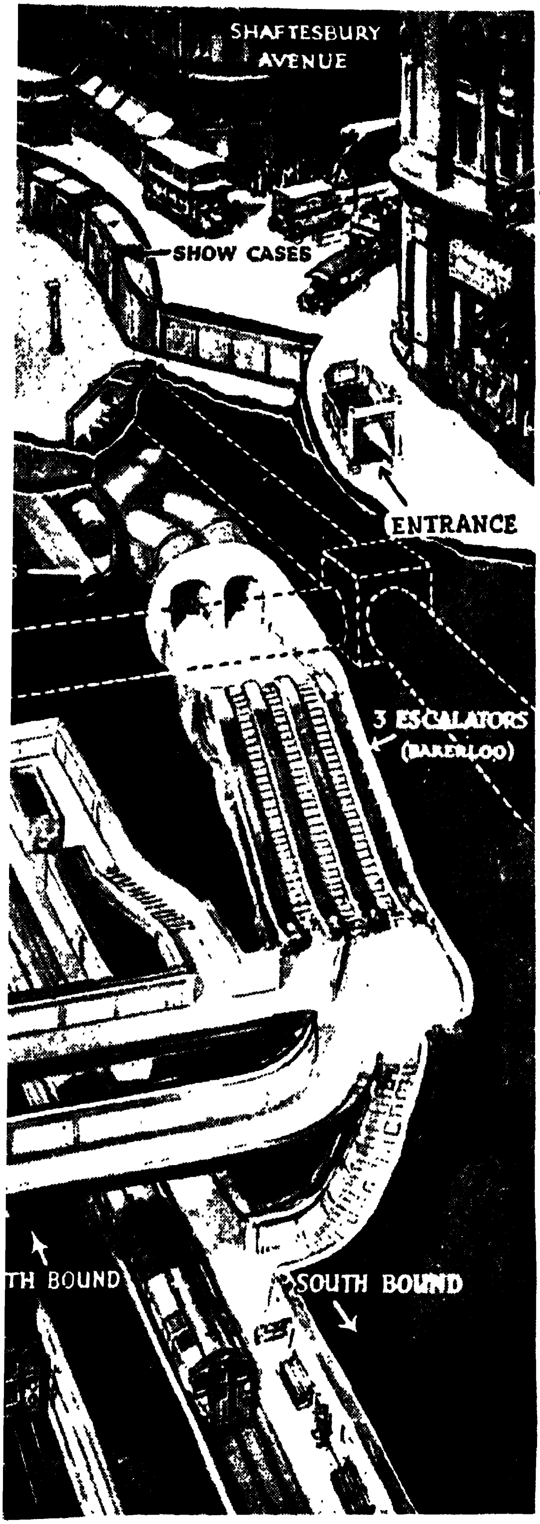
Traffic loads. Signalling by track circuit. Train stops. Dead man's handle. The automatic junction. The train describer. Headway clocks and charts. The lay-out of terminals and junctions. Ticket machines. Design of cars. Some emergency devices. Ventilation.

It is appropriate that the largest city in the world should have developed the most efficient system of mass passenger transport that the world has yet seen. Since 1933 all the passenger services of the London area, except those of the main line railway systems, have been concentrated under the direction of the London Passenger Transport Board, and the operations of this authority have produced statistics in regard to passenger handling that are truly astronomical. The latest records available show that in a single year the trains of the London Passenger Transport Board carried 410,479,000 passengers, or nearly half the number—850,243,000—carried by all four British main line railways. These four—the London, Midland and Scottish, the London and North Eastern, the Great Western and the Southern—between them operate 19,378 miles of line; the London Passenger Transport Board conducts its operations over 122 route miles of its own line, and over 209 miles of line owned by other companies. This means that while the main line railways are conveying an average of 43,876 passengers annually over each route mile of their lines, the corresponding figure for the London Passenger Transport Board lines is over 1,240,000 passengers each year.

Again, the main line railways need just under 20,000 steam locomotives (which, of course, are used for freight as well as passenger traffic), 2,200 electric motor coaches, and over 42,500 passenger coaches to carry on their work. The London Passenger Transport Board has in use only 1,750 electric motor coaches, 1,880 trailer coaches, and, for outer London work, forty-seven electric locomotives and seventy-four passenger coaches. Such statistics as these are an essential preliminary to any study of the working of the London tube system, as they give some indication of the nature and complexity of the problem which has to be solved in this mass handling of passengers day after day over relatively limited lengths of track and with a limited amount of rolling stock.

It is with the fifty miles of deep level twin tube tunnels and their operation that the present description is more particularly concerned. As these have become linked up by degrees with one another and with the surface railways, the length of journey has gradually increased, until the record of thirty-two miles, with thirty-five intermediate stops, has been reached by the Piccadilly tube trains on their journey between Cockfosters and Uxbridge, taking just over eighty minutes for the through run. Another record, incidentally, is that of the combined Northern and City lines, which are continuously in tunnel for sixteen miles, 1,100 yards, between


ENTRANCE
ENTRANCE
ENTRANCE
ENTRANCE
BOOKING HALL
SWITCH HOUSE
MACHINERY FLOOR
ENTRANCE
CHANGE KIOSKS
AUTOMATIC BOOKING OFFICE
AUXILIARY BOOKING OFFICE
5 ESCALATO
PIPE
EAST BOUND
3 ESCALATORS (PICCADILLY)
INTERCHANGE
PICCADILLY
BAKERLOO
STAIRCASE TO STREET
WEST BOUND

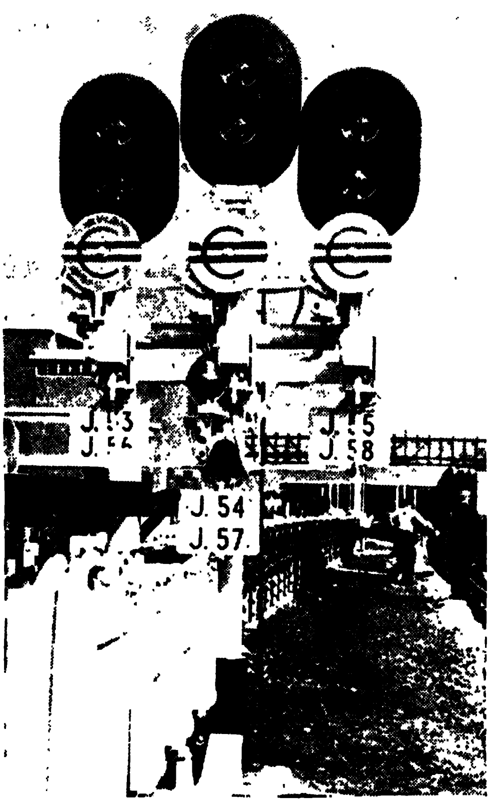


Golders Green and Morden—easily the longest railway tunnel in the world.

The maximum frequency of service reached on the tube lines is forty trains per hour per track, at the rush periods—in exceptional cases a maximum of forty-three per hour, or an average of one every eighty-four seconds, has been attained—and the maintenance of such a frequency calls for exceptional measures both in regard to safety and the handling of passengers. Except at junctions, the signalling of the tubes, both below and above ground (Figs. 1 and 2), is entirely automatic. The principle is that of track circuiting, whereby a weak current, carried by the running rails, is short-circuited direct from one rail to the other by the wheels and axles of any vehicle running over that section of track. Fig. 3 shows an imaginary section of line with two stop signals, S. 1 and S. 2. The track circuits connected with the signals are roughly the same length as the distance between the latter, and are insulated from each other at gaps A, B and C.

Directly the first pair of wheels of the train enters the section AB, the relay is broken down by this short circuiting, and signal S. 1 goes to danger; S. 2 similarly goes to danger as soon as the section BC is entered. But the entry to BC does not immediately restore signal S. 1 to the clear position, as the section between signals S. 1 and S. 2 has not been cleared until the last vehicle of the train has passed B, and so has come within the protection of signal S. 2. When the last pair of wheels in the train has run beyond C, however, the

UNDERGROUND STATION IN SECTION
Our illustration, adapted from a drawing by D. Macpherson for the London Passenger Transport Board, shows a general plan of the station at Piccadilly Circus. It took four years to construct and deals with 50,000,000 passengers annually. Seven entrances lead from street to booking hall, and eleven escalators to the various platforms here shown in section



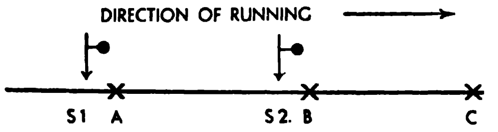
AUTOMATIC SIGNALS
Figs. 1 and 2. The signalling of the tubes, both below and above ground is automatic, except at junctions. The tripcock, shown at right, provides against any failure of the human element, rising when the signal is at danger and applying the brakes.

relay is once more energized through the rails between B and C, and S. 1 returns to the normal, or clear indication.

Such precautions would have a limited value only unless provision had been made against the failure of the human element in the motorman's compartment. Working in conjunction with each stop signal, therefore, is a tripcock (Fig. 2) which rises to a vertical position when the signal is at danger. If by negligence, or for any other reason, a driver should attempt to pass the signal in the danger position, the cock intercepts a co-acting lever on his motor coach, cutting off the current and applying the full force of the air brakes, which is sufficient to pull up the train within its own length. It may be remarked here that the Westinghouse system of compressed air braking is in use on the tubes, and that the latest stock has the clasp type of brake, with blocks acting on both sides of each pair of wheels. Collisions on tube lines are thus

TRIPCOCK

virtually impossible, and the one or two instances of such casualties that are on record have been due, not to any failure of the appliances, but to improper action by some members of the staff, against the possibility of which further precautions have since been taken.

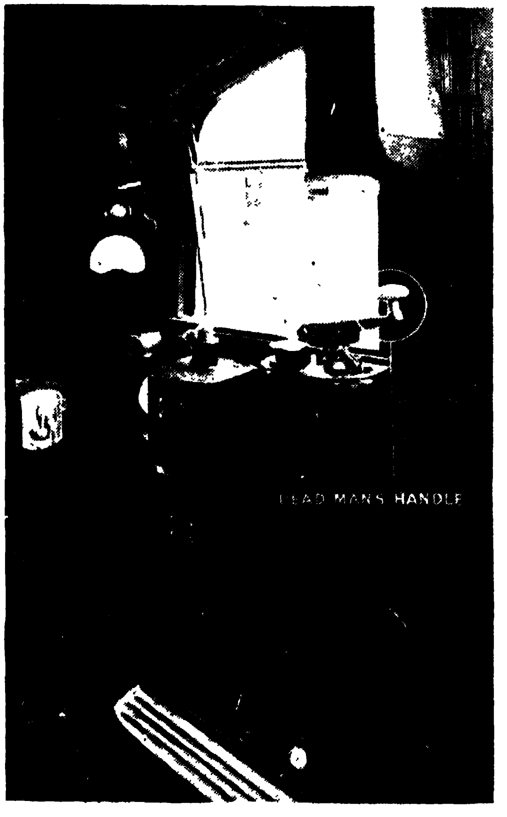


SIGNALLING BY TRACK CIRCUIT

Fig. 3. This diagram shows the principle of signalling by track circuit. S. 1 and S. 2 are stop signals. A weak current is short circuited from one rail to the other by wheels and axle of train. The track circuits are insulated from one another at gaps A, B and C. When the train enters section AB the relay is broken down and S. 1 goes to danger: similarly with BC and S. 2. When C has been passed S. 1 returns to clear.

In addition to the train-stopping device, protection is necessary against the possible consequences of a driver's sudden indisposition. This is made by the well-known "dead man's handle," which is actually a knob on the top of the current controller in the motorman's cab (Fig. 4). The knob works against a spring so light in its action that the driver can keep it continuously depressed, without effort, by the pressure of the palm of his hand throughout the time that the train is in motion. If his hand is removed, or the pressure relaxed, the knob instantly rises, cutting off the current and applying the brakes on the train. A third safety precaution is the brake governor, an electro-pneumatic device which makes it impossible to pass current to start the train unless the air pressure in the train-braking system is at least 50 lb. per sq. in., and full braking control is therefore available.

In the tubes the operation of signals and train stops is largely electro-pneumatic, with air at 60 lb. per sq. in. pressure, and the hiss of signal movements as signals are passed is often audible to passengers riding near the leading end of the trains. On certain of the more recently opened sections, particularly those above ground, all-electric signalling is in use. For the most part only two-aspect indications—red and green—are used, without the yellow caution indication, as the close headway at which the trains run, and their uniform speed and rate of acceleration and deceleration, make the additional complication of the caution aspect unnecessary. In the open, fog repeater signals are provided, a short distance ahead of the stop signals—exactly repeating the indications of the latter but of a clearly distinctive appearance—so that in thick weather drivers may have an advance

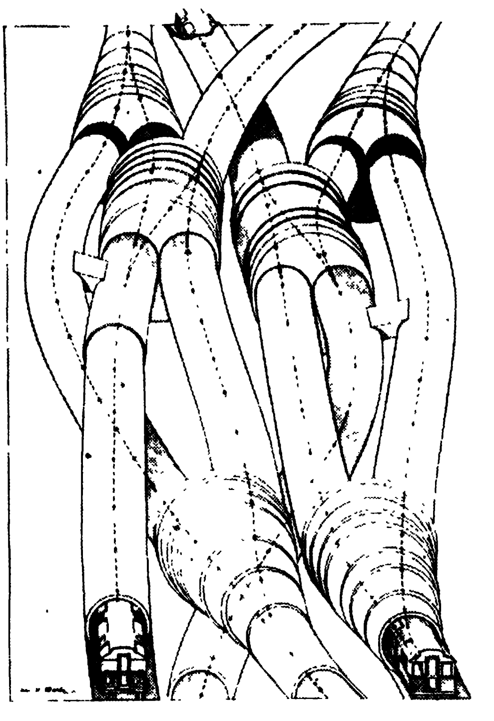


DEAD MAN'S HANDLE

Fig. 4. The knob on the current controller in the motorman's cab works against a light spring depressed by the driver's hand. When pressure is relaxed the knob rises and the brakes operate.

warning of signal indications. This makes it possible to dispense with fog signalmen and detonators.

Automatic signalling not only expedites the working of the trains, but also effects considerable economies in operation by dispensing with signalling personnel. It is not possible, however, to apply the same method to junctions, where varied movements of trains from track to track make it impossible to do



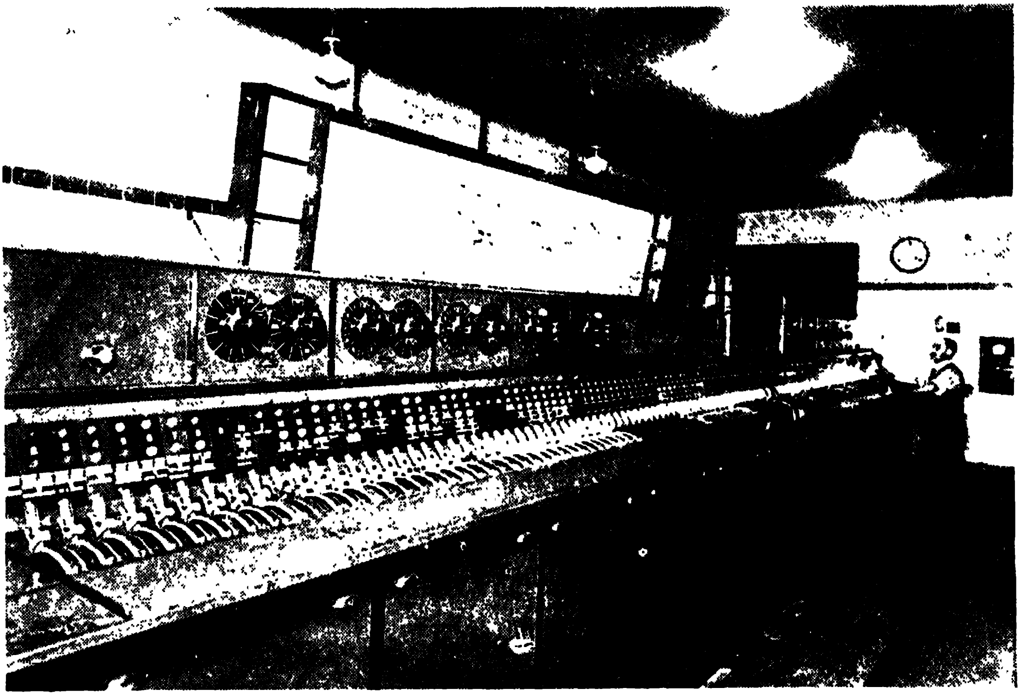
A FLYING JUNCTION

The junction at Camden Town where the Northern and City lines meet, is a good example of the flying or burrowing junction. Trains pass either under or over every other conflicting track in an extremely complicated layout.

without the human element. The nearest approach to automatic junction working is at Wood Green, on the Piccadilly line, where certain trains terminate and begin their journeys, and can be worked into and out of the lay-by siding without the signal box being manned. To speed up the tube working at junctions, so that it may equal the speed with which the trains are passed over the ordinary stretches of track by automatic working—and otherwise, of course, the junctions, like bottle-necks, would slow down the entire system—every conceivable electrical aid, both visual and operational, is brought into use.

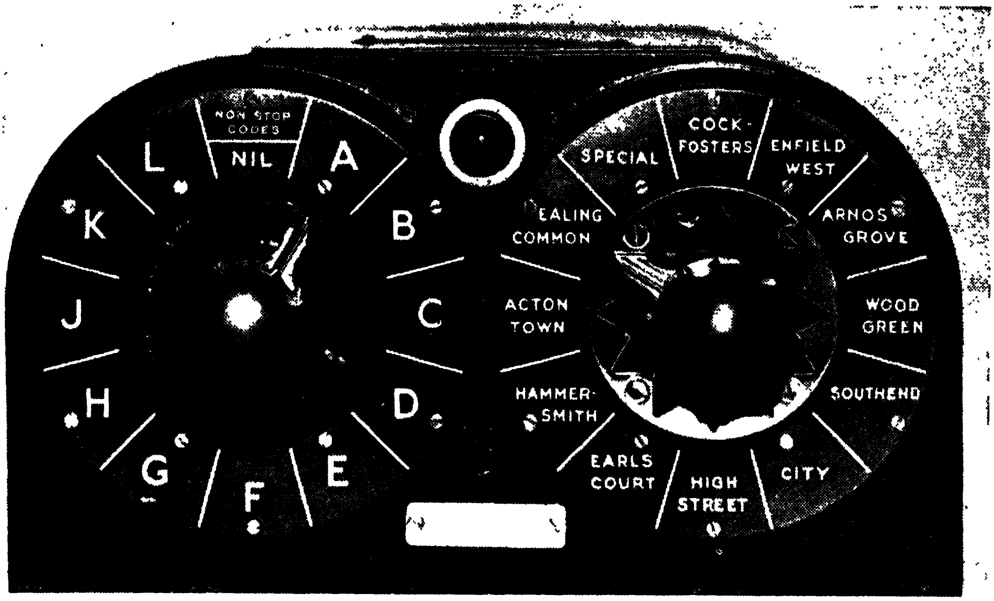
These aids include electrical or electro-pneumatic operation of signals and switches by miniature levers that can be flicked over with a touch of finger and thumb, and illuminated track diagrams (Fig. 5), which show all the lines controlled by each cabin, and, by means of small lamps in lines along each track on the diagram, exactly what sections are occupied by trains at any given moment. It is thus unnecessary for the signalmen to be actually in sight of the trains that they control; at Camden Town, for example, where eight tube tracks meet in an extremely complicated layout, the trains passing over six of them are invisible from the signal box. Each signal worked from these junction cabins is arranged to return to danger immediately a train has passed it, similarly to the fully automatic signals; in the signal box small electric lights, immediately above the lever concerned, repeat the indication that the signal is showing at any given moment. Signal boxes at which the points only require to be used during parts of the day are manned for those periods only; at other times the pulling over of a king lever locks all switches in position for the through roads, and throws the section past the box into automatic working.

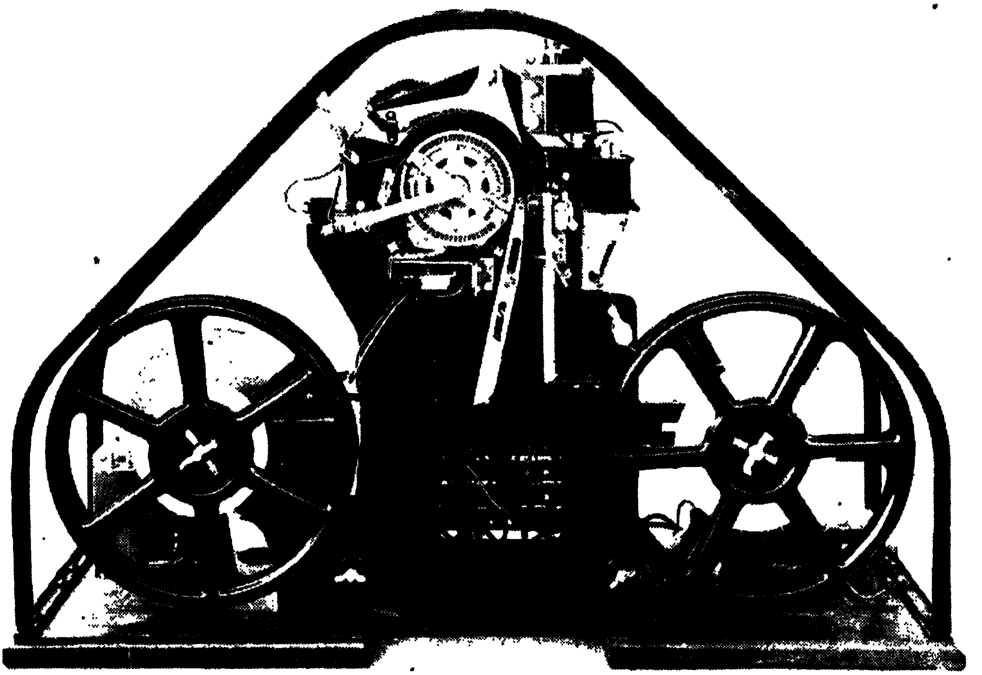
It is necessary for signalmen at junctions to have an advance indication of the destination of all approaching trains. This is done by means of ingenious electrical train describers, which are also used to indicate to passengers, by means of the platform indicators, the sequence in which trains are approaching, and the stations to be missed by non-stopping



HOW ELECTRIC AIDS TO AUTOMATIC WORKING ARE USED BY A TUBE RAILWAY

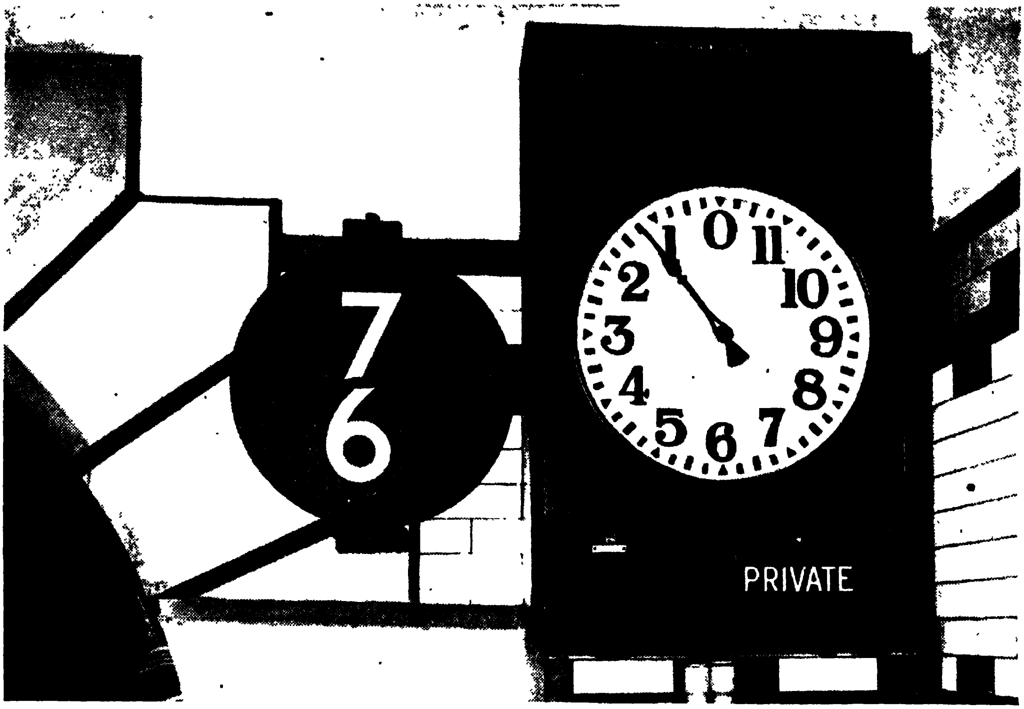
Fig. 5. The photographs show the track outside Acton Town Station and the signal cabin at the same station, where the track is represented by an illuminated diagram. Small lamps in lines along the diagram show exactly what sections are occupied by trains at any given moment. Thus the signalmen do not need to be in sight of the trains they control. Signals and switches are operated electrically by miniature levers that can be flicked over with the touch of a thumb. To maintain speed at junctions every mechanical aid possible both visual and operational is brought into use.





HOW THE DESCRIPTION OF A TRAIN IS SENT ALONG THE LINE

Fig. 6. The ribbon-storage train describer, here illustrated, is the means by which the signalman sends a description of the train along the line, this being communicated to passengers by illuminated signs on the platform. Above is the transmitter and below the receiver. The storage of the descriptions is carried out by punching holes in a paper ribbon, 7 in. of which is threaded through the instrument to correspond with each train description. The position the holes occupy decides the description shown on the platform indicator. The descriptions are read off the paper, by passing it round a wheel carrying contact pins which pass through the punched holes, completing an electrical circuit and lighting the sign, which can be read by passengers on the platform.



HEADWAY CLOCKS HELP TO MAINTAIN THE CORRECT INTERVAL BETWEEN TRAINS

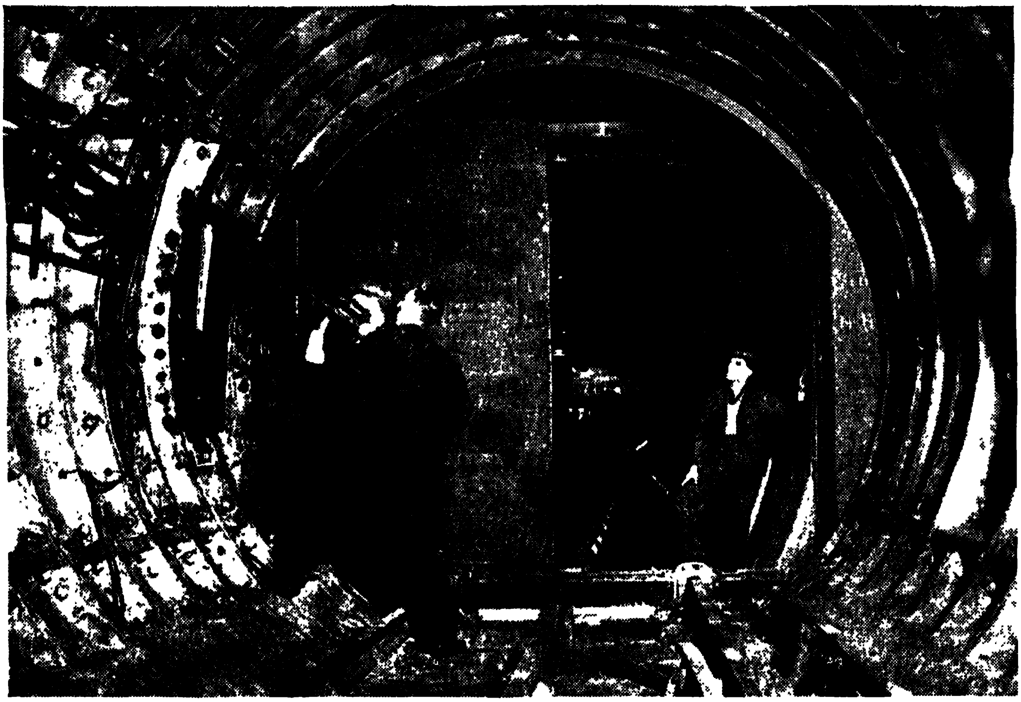
Fig. 7. Headway clocks are placed at the mouths of tunnels at certain stations, facing the drivers. The hand is reset to zero as each train passes, then rotates clockwise. The dial has twelve one-minute divisions, and thus the driver is able to see how far ahead the next train is running.

services (Fig. 6). The train describer employs a paper ribbon, similar to that in use on telegraph instruments, and as the description of each train is fed into the apparatus at the starting point, the ribbon is perforated to correspond with its destination and intermediate stops. A series of impulses is used for this purpose, negative impulses resulting in blank spaces on the ribbon, whereas reversal of the polarity of the current gives a positive impulse and perforates the ribbon. The signalman working the transmitter has merely to set the pointers on the destination and non-stop dials of the apparatus to the appropriate positions, and this causes a ratchet magnet to drive round a ratchet wheel and a contact arm step by step until the describers up to twelve destinations and fifteen variations of stops are provided for. The receiving apparatus is on somewhat similar lines, and cancellation by each train of its own description, as it passes, is automatically carried out. A lengthy loop of the ribbon in both transmitting and receiving apparatus stores the train descriptions from the time when they are fed into the transmitter until cancelled by the passing train.

To assist in preserving the correct interval between trains, headway clocks are installed at the mouths of the tunnels at certain selected stations, facing the drivers (Fig. 7). The hand of the headway clock is reset to zero as each train passes, and then begins to rotate in a clockwise direction, the dial having twelve one-minute divisions. The driver thus sees exactly how many minutes ahead the next train is running, and is able to regulate the running of his own.

Headway charts have a similar function, but administratively (Fig. 8).

TUBE EXTENSIONS—A TUNNEL UNDER CONSTRUCTION
A section showing above the additional tunnel made first to remove the earth to the surface.

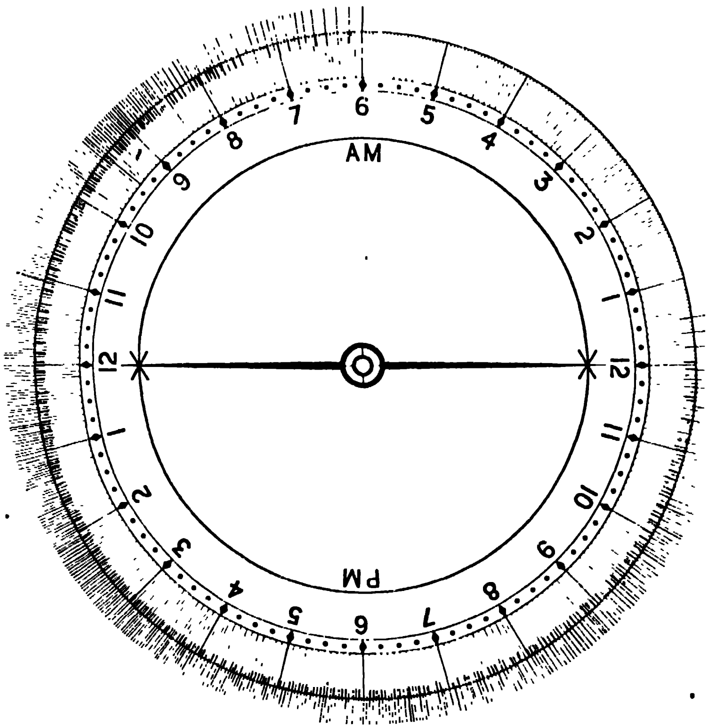


HOW PROTECTION IS GIVEN AGAINST FLOOD
The photograph shows the steel door and emergency hatch—both of which are part of the elaborate precautionary measures taken to guard against the danger of flooding in the tube

Most tube travellers using Piccadilly Circus tube station have been attracted, no doubt, by the six dials let in the wall of the circulating area, with the intriguing invitation above "See how they run." Each dial represents one section of the London Underground system; and at a selected point on each of these lines an electrical contact is fixed, operated as each train passes, and causing a small inked hammer to strike the fringe of the dial of the line concerned. A sheet of paper is fixed on the dial, divided up into the twenty-four hours of the day, and taking the entire twenty-four hours to make the complete rotation. If the services are operating normally, the ink marks on the periphery of each dial should be evenly spaced, but any abnormality in running causes gaps to become visible in the sequence, and directs immediate attention to the line concerned. It was primarily for the controllers' offices that these headway charts were devised, and although they give no indication of the cause of the delay, they bring it under immediate notice, and set in motion necessary machinery to have the trouble rectified.

The design of junctions and of terminal or partly terminal stations on tube lines requires the greatest care, if they are to be worked without interfering with the steady flow of the trains. The ordinary double line junction, which requires trains to cross one another's paths on the flat, would make it impossible to maintain a service frequency of one train every one and a half minutes. The flying, or burrowing, type of junction is therefore used, in which a diverging train passes over or under the opposite track, as the case may be.

Of this a remarkable example is the junction at Camden Town, on the Northern and City tube lines (page 164). Originally the twin tubes of the Charing Cross, Euston and Hampstead line, as it then was, branched into four at Camden Town, two tubes proceeding to Golders Green and the other two to Highgate. In



HEADWAY CHARTS PERMANENTLY RECORD TRAIN MOVEMENTS

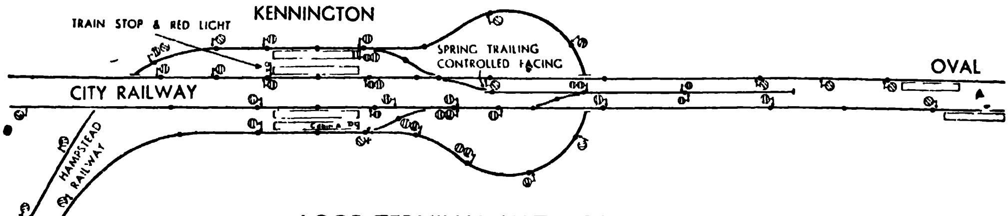
Fig. 8. The circular headway chart is divided into hourly spaces. It revolves and as each train passes out of the station an electrical contact causes a hammer to descend on an inking ribbon, stamping a short line against the exact line on the paper dial. A permanent record of the headways of trains throughout the service is thus to hand daily which may be checked against the scheduled times. Its main value is in providing data for the guidance of the administrative staf

A TERMINAL LAYOUT WITH CROSS-OVER

Fig. 9. This is a two-platform station with double cross-overs between the tracks and two sidings at the east end. An eastbound train proceeds into A siding and reverses into the departure platform. This enables a train which is following closely to be run into B siding.

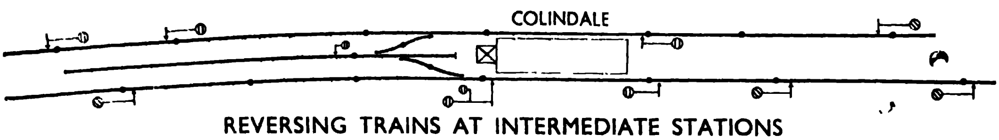
1924 an extension of the two tubes of the City and South London from Euston was brought into the Camden Town junction, which is now, therefore, a deep level junction of eight tubes with one another. As seen in our diagram, this labyrinth has been so laid out that whether trains are travelling from the Northern line to Golders Green or Highgate, or from the City line to either of these destinations, or vice versa—eight routes in all—no train crosses the path of any other, but always either over or under every other conflicting track. Further, services of equal intensity are maintained over all four pairs of tubes, in roughly equal proportions.

The simplest type of terminal is the loop, which makes possible continuous running without reversal of the trains, and also allows of one platform sufficing for all inward and outward traffic. Points, cross-overs, and a signal box are unnecessary; there is no obstruction or delay while a train crosses from the down to the up road or vice versa; the train crew do not require to change ends; and the terminal stop can be reduced to one of the same duration as that at an intermediate station. But this plan has also considerable disadvantages. Chief among them is the fact that the absence of any layover at the station makes it difficult to correct late running, while a defective train may hold up the entire service, owing to the impossibility of stowing it out of the way, even temporarily. The single platform for all traffic may also lead to congestion. At the original Charing Cross terminus of the Charing Cross, Euston and Hampstead tube, and also at Wood Lane on the Central London, it was originally in use, and at Wood Lane and Kennington it is still in partial use.



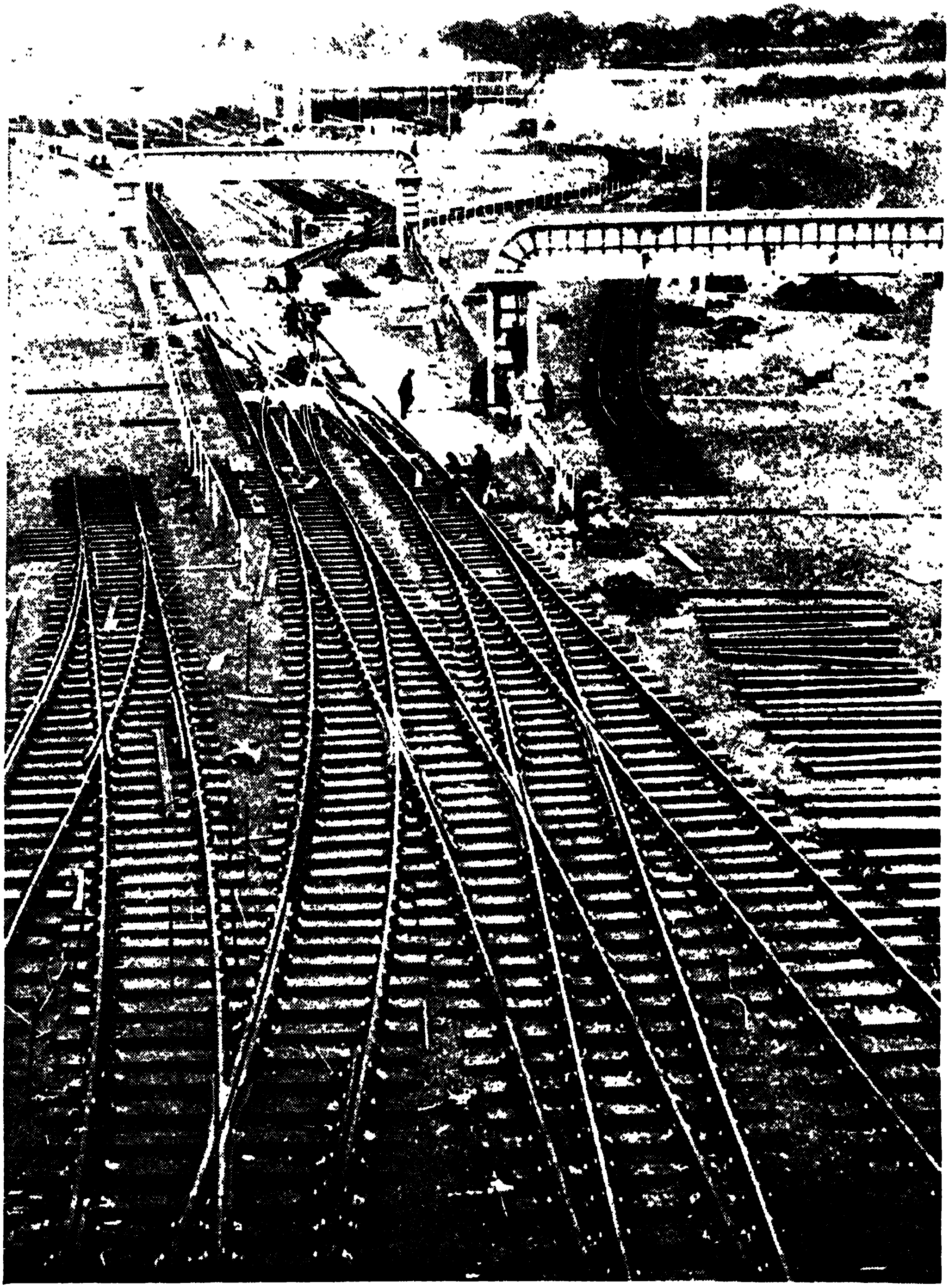
LOOP TERMINAL WITH CENTRAL BAY ROAD

Fig. 10. The advantage of a loop terminal is that it makes possible continuous running without reversal of trains, one platform sufficing for all inward and outward traffic. A disadvantage is that the sharp curve imposes a severe speed limit, and that a defective train may hold up the whole service. At Kennington station here shown, however, a central bay road is used for reversing trains or for starting defective trains. Trains also go straight through without hindrance.



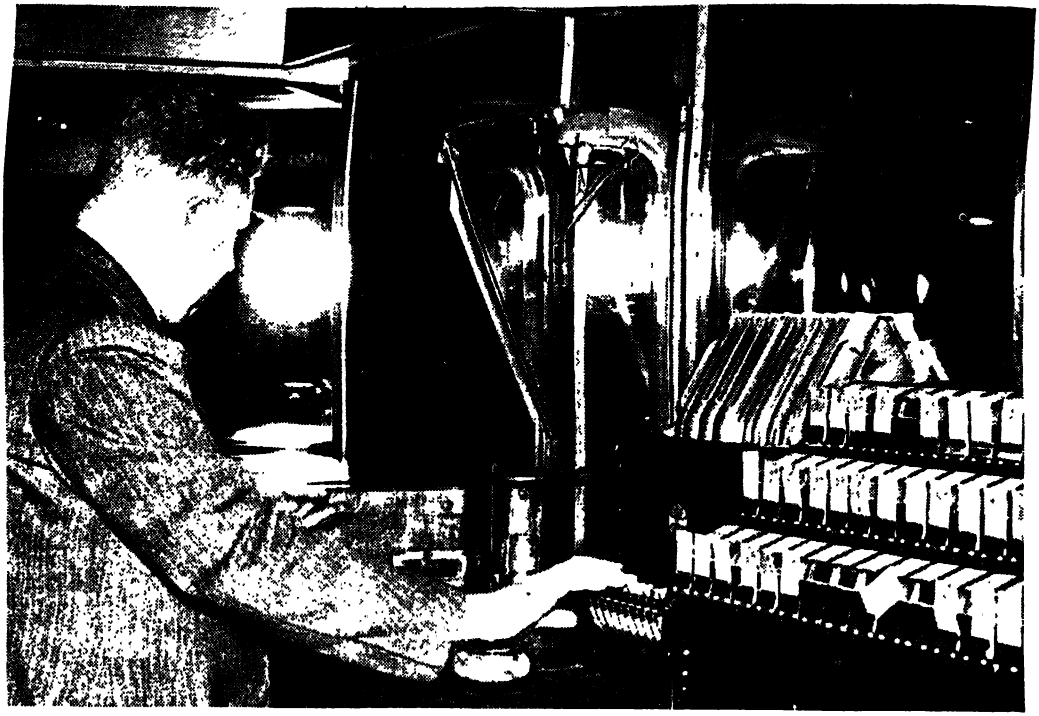
REVERSING TRAINS AT INTERMEDIATE STATIONS

Fig. 11. Intermediate stations may be equipped with a central or side bay road for reversing trains. Where the tube services reach the outskirts of the City and do not require the same frequency of service as the inner areas, these are a distinct advantage. Our diagram shows the layout at Colindale where trains are allowed a period of five minutes from arrival at the down platform to departure from the up platform. The central bay enables trains to be reversed withou fouling either of the running roads. Side bays, although also used, are less satisfactory to operate



LAYING THE TRACKS FOR A TUBE EXTENSION

This view of a North London extension of the Piccadilly tube in course of construction shows cable bridges, siding, cross-over and loop terminal. The layout of tracks and terminals is carefully planned to ensure minimum congestion and delay of traffic. Compare the diagrams on opposite page.



USING THE CHANGE MACHINE AT A BOOKING OFFICE

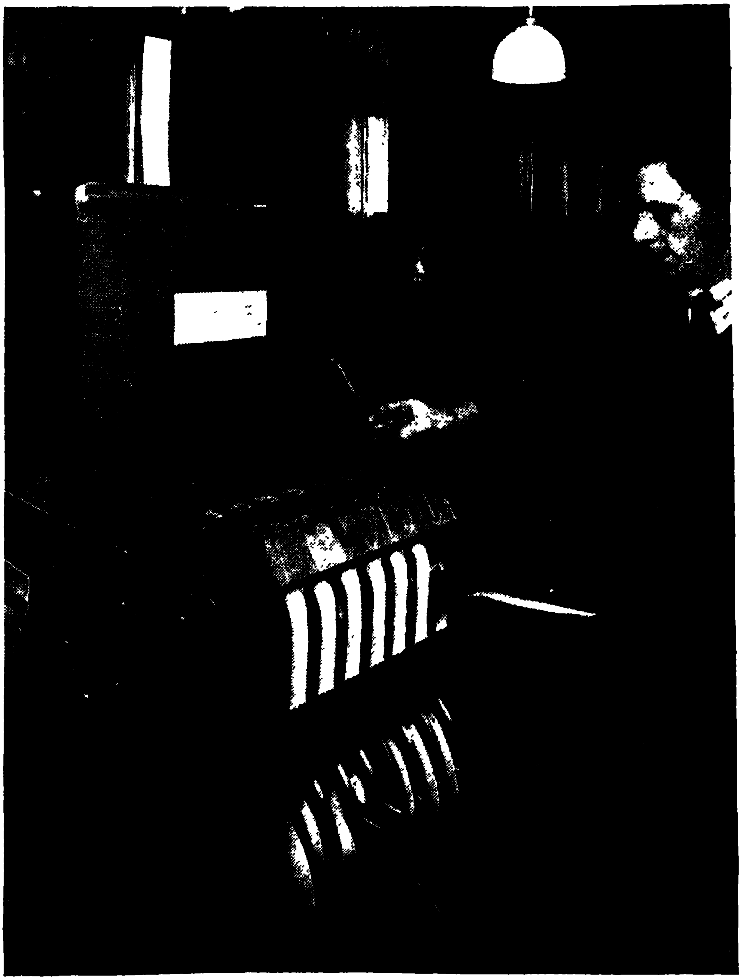
Mechanical aids such as the change machine speed up the work of booking, and one booking clerk is capable of issuing tickets at the rate of over 1,300 an hour, or twenty-four a minute.

A typical terminal layout that offers maximum possibilities in relation to its simplicity is that at Liverpool Street, Central line, before the opening of the extension of this line eastwards to Stratford and beyond (Fig. 9). This is a two-platform station, with double cross-overs between the two tracks at both ends of the station, and two sidings prolonging the running roads at the east end. The normal procedure is for an eastbound train to run into the arrival platform, unload its passengers, proceed into A siding, and reverse over the east end cross-over into the departure platform. If two trains approach the arrival platform on a very short headway between each other, the second can be run over the east end cross-over into B siding, and reverse direct from there into the departure platform. If a long headway has developed between two trains, on the other hand, an arriving train can be run direct over the west end cross-over into the departure platform, where it is ready for immediate departure, and part at least of the delay can be recovered. Compared with the loop arrangement of a terminal (Fig. 10), reversal on the Liverpool Street plan takes about three minutes, and requires an additional train and crew in the service, but the greater elasticity of the scheme makes this addition well worth while.

Now that so many of the tube services have been projected well into the outskirts of London, which do not require the same frequency of service as the inner areas, reversal of trains takes place at various intermediate points, such as Wood Green, Arnos Grove, and Enfield West on the Cockfosters line; Golders Green and Colindale on the Edgware line; East Finchley and Finchley Central on the High Barnet line, and so on (Fig. 11). At certain of these stations a

single lay-by line is provided between the running roads, the trains that are reversing running direct into the lay-by, and at the appropriate time out on to the opposite track. In emergencies, also, these lay-by stations are valuable, as they enable trains to be reversed expeditiously at points short of their destination, in order to correct abnormal gaps that may have opened out in the service operating in the other direction. It is inevitable that such emergency reversals should cause annoyance to through passengers, but such infrequent happenings are part of the suffering of small minorities that help to relieve otherwise inevitable congestion in the Central London areas, and to maintain systematic service. The cumulative effect of any kind of delay on such high frequency services as those of the London tubes needs but little imagination to be realized.

Equal efficiency directs the work of handling the passengers. The first business is that of tickets. Almost from the start much of the booking office work was replaced by automatic machines. At first these required to have inserted the exact number of coppers corresponding to any given fare, but the latest electrically operated machines either accept coppers, or give the appropriate change for sixpence or a shilling. This affords further relief to booking offices, for investigations have shown that while from 42 per cent to 57 per cent of passengers booking at a booking office window during a rush period require change, from 75 per cent to 86 per cent of the coins tendered are shillings and sixpences. Batteries of ticket machines, each issuing a ticket of a different denomination, are now a familiar spectacle at all busy tube stations, and it is at these machines



CHARGING A TICKET MACHINE

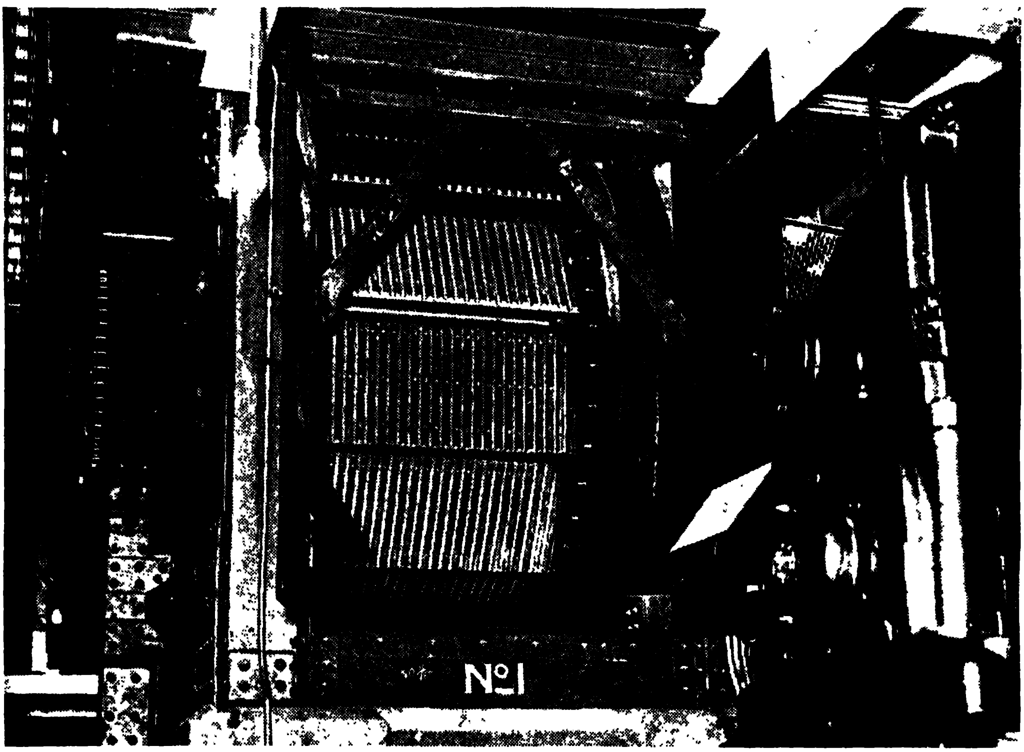
Fig. 12. Issue of tickets is largely carried out by automatic machinery. Electrically operated machines, fed by long rolls of plain ticket paper, print each ticket and eject it on pressure of a single button.

that a large proportion of the public obtain their tickets.

As to the booking offices themselves, the bulk of the ticket issue is by ingenious automatic machinery. The latest machines, electrically operated, and fed by long rolls of plain ticket paper (Fig. 12), print each ticket with the date, station of origin, destination, and other particulars, cut it to length, and eject it ready to the passenger's hand, on pressure of a single button. Such is the speed of their operation that four tickets can be issued per second; the daily changing of the date is a matter of fifteen seconds; a new paper roll can be inserted in thirty seconds; and a defective unit can be replaced in its entirety in fifteen minutes. Individual ticket racks are needed only for certain varieties of tickets that are in less general use. Change machines assist the work of giving change, and minute study has even been given to the shape of the depression at the booking office window into which the change is put, so that it may be picked up by the passenger without fumbling, and in a minimum of time. Tests of the speed of booking with modern appliances have shown that, apart from the assistance given by the purely automatic ticket machines, a single booking clerk can issue tickets at his window at the rate of over 1,300 an hour, or roughly twenty-four a minute.

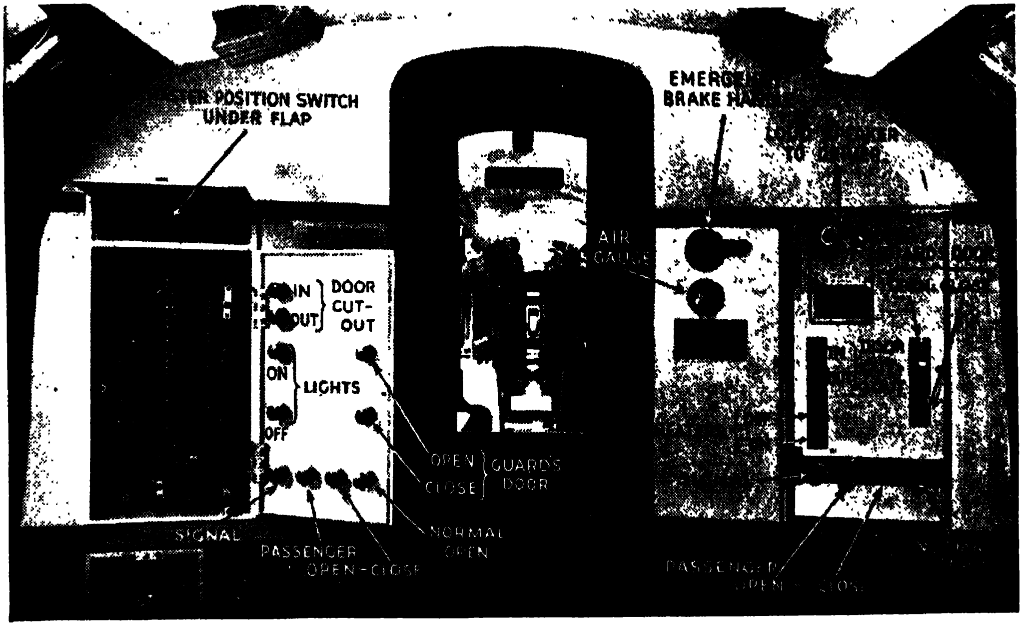
ESCALATORS

The next business is to get passengers as expeditiously as possible to and from the trains. With deep level tubes stairways were, of course, impossible, and



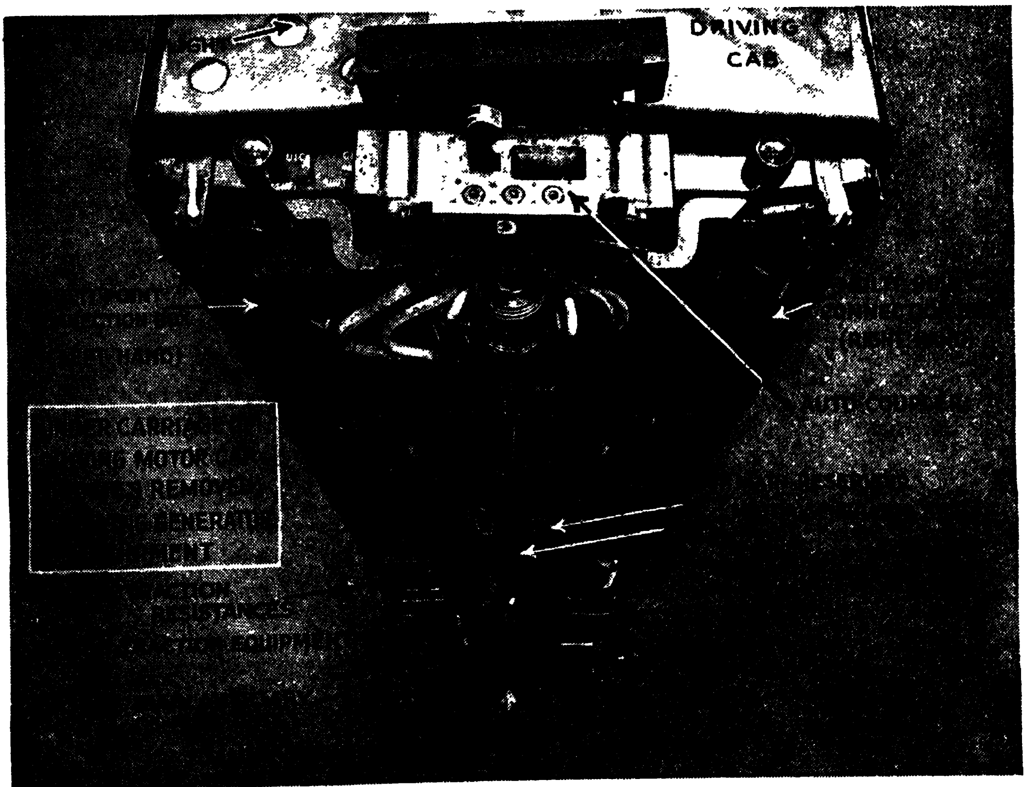
REVOLVING DRUM ON WHICH THE ESCALATOR TREADS TURN

Fig. 13. The escalator has become a definite contribution to solving London's traffic problem, as it permits an even flow of passengers. The steps are of steel with wood treads, and are carried between two main driving chains, which are kept travelling at an even speed of one mile per hour.



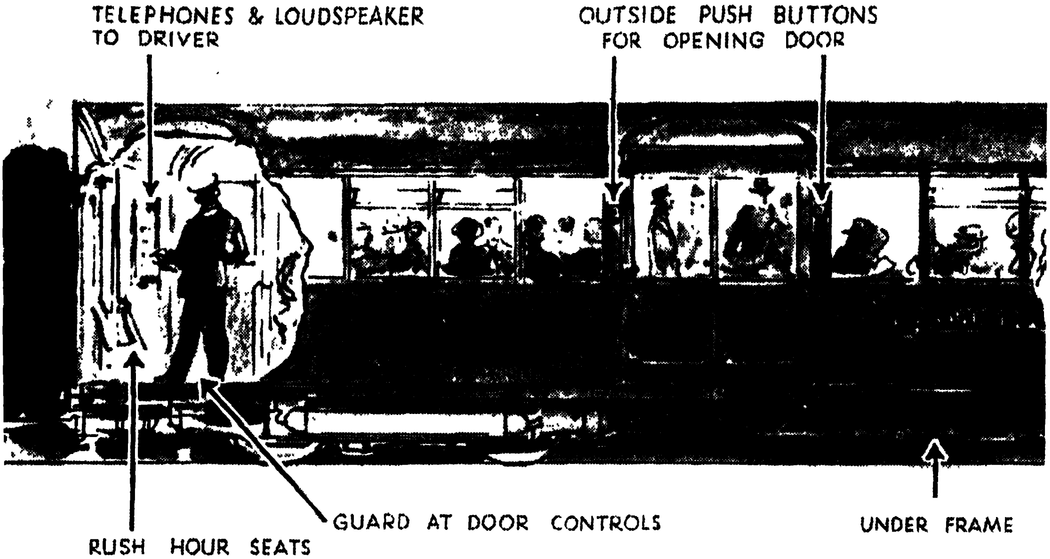
EQUIPMENT OF THE GUARD'S PLATFORM

Fig. 14. From his end platform the guard operates the pneumatic doors, of which there are four sets to each car. An electrical device shows when doors are closed. Details are seen above.



PROPELLING MACHINERY UNDER THE CAR FLOOR

By careful planning all the propelling machinery can be thus located to save passenger space.



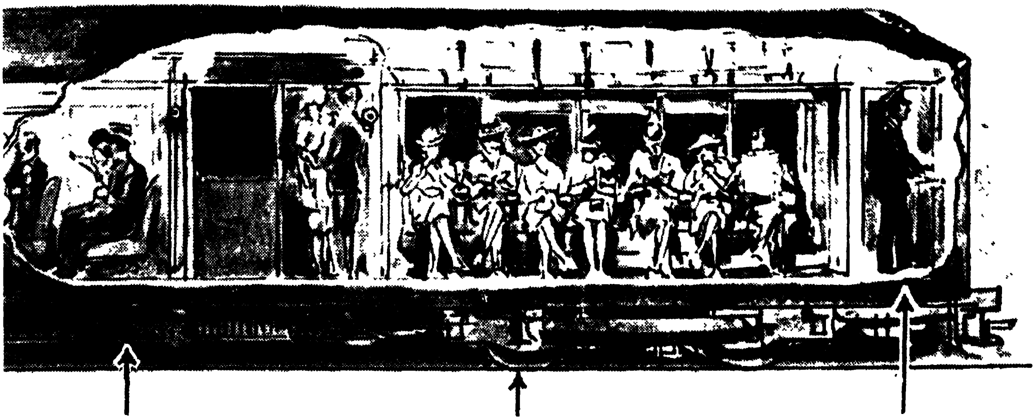
A TUBE TRAIN IN SECTION, SHOWING MEANS OF

The present arrangement and equipment of tube stock is the fruit of years of experiment, both in producing comfort for the passenger in a minimum of space and, at the same time, maximum speed of ingress and egress. This sectional view shows the make-up of a tube train. Ample circulating space is provided near the doors to allow plenty of room for movement of passengers. Thus the

at first, lifts were universal; but despite considerable increases in the speed of lift movement, the steady growth of traffic has made still greater carrying capacity necessary, and this has led to the development of the escalator system (Fig. 13). The tube escalators, though more expensive to instal and needing considerably more space than lifts, give continuous service, and do not need to be manned. Further, the passenger, by walking up or down the stairs of the escalator, as the case may be, can more than double the escalator speed. A modern comb-type escalator in which the passenger steps on or off the stairs in a straight line (instead of to left or right, as in the earlier types), is reversible, and this principle is used at certain busy stations, where three parallel escalators are installed, two of the escalators being kept in motion together in the direction of the heavier traffic, and the third in the direction of the lighter traffic; at slack periods one escalator is stopped altogether. At stations where the lines are located at exceptional depths, the escalators are usually in two independent stages, with an intermediate landing, as at Piccadilly Circus (page 160), Holborn, and elsewhere.

THE TUBE TRAINS

Of equal importance in the handling of passengers is the design of the cars. The present arrangement and equipment of tube stock is the fruit of years of experiment, both in producing comfort for the passenger in a minimum of space, and at the same time maximum speed of ingress and egress. The latest tube standard coaches are 52 ft. 4 in. long (motor coaches) and 51 ft. 3 in. long (trailers) by 8 ft. 10 in. wide, but the point wherein they differ most from surface stock is in height, which is only 9 ft. 6 in. from rail, as compared with an average of 12 ft. 6 in. with ordinary



COMMUNICATION BETWEEN GUARD AND DRIVER

number of seats is only from forty to forty-four. The doors work on roller bearings, and are operated by the guard in his platform. The speed of a pair of doors is retarded as they approach the point of meeting when the lightened pressure and the rubber edges of the doors prevent possible injury to passengers. Guard and driver can communicate by means of a microphone

stock. Wheels of very small diameter are used—3 ft. on the motor-driven and 2 ft. 9 in. on the ordinary bogies—and this makes it possible to build the bodies low on the wheels, giving adequate standing room for passengers inside the limited cross section of the body. Current throughout the Underground system is universally 600 volts d.c., with conductor and independent return rails. Speed is high with the present standard 168 h.p. motors. A seven-car train is propelled by ten motors totalling 1,680 h.p., and is easily capable of speeds up to 60 m.p.h. The cars are streamlined in order to reduce atmospheric resistance to a scientific minimum.

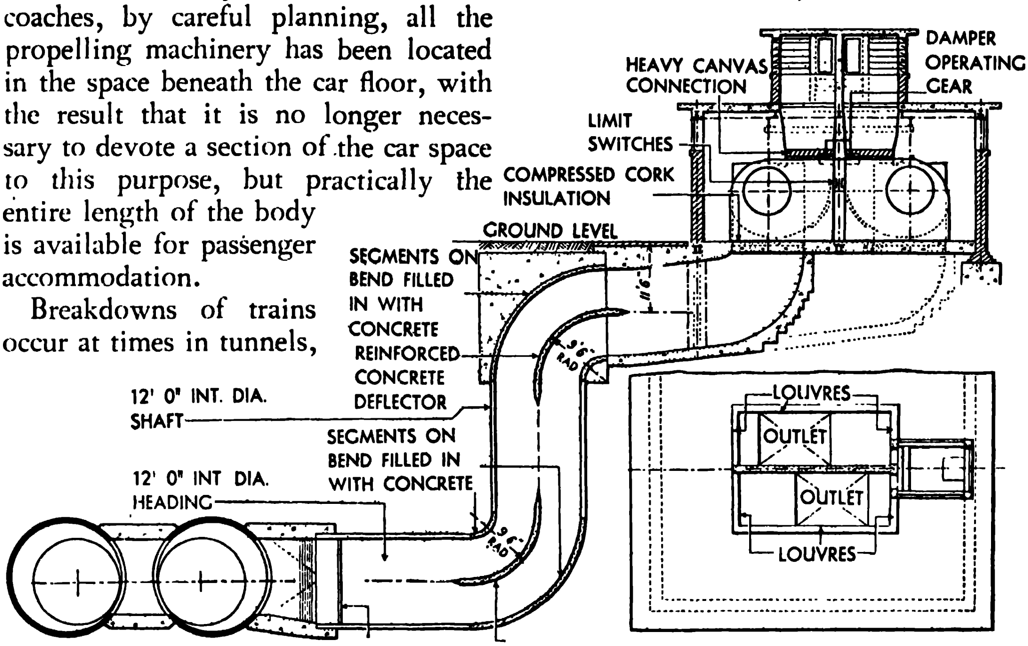
Tube trains are normally made up to six or seven cars, and with 250 to 290 seats per train, there is adequate seating for all slack hour needs, as well as for the extremities of the journeys even in rush hours, when passengers travelling the longest distances are reasonably assured of seats. But at times and over sections in central London where the pressure is greatest, it is intended that a proportion of the passengers shall stand, to limit the train formations.

All the cars are provided with four sets of pneumatically operated doors, 4 ft. 6 in. wide, two on either side of the car, and the latest cars have narrow end doors as well. Ample circulating space is provided between and adjacent to the doors, so that there may be plenty of room for movement of passengers up and down each car; it is for this reason that the number of seats in each modern car is only from forty to forty-four. The doors work on roller bearings, and are operated by the guard from his end platform by electrically controlled air engines, the speed of a pair of doors being retarded as they approach the point of meeting, when the pressure is lightened sufficiently—in conjunction with the rubber door edges—to prevent

injury to any passenger who might happen to be between the doors at the moment of closing. An electrical device shows the guard when all the doors are properly closed, and enables him to transmit to the driver the bell signal which frees the latter's controller and enables him to start the train. By means of a microphone and loudspeaker circuit, also, the guard and driver of each tube train can speak direct to one another whenever necessary. On the latest motor coaches, by careful planning, all the propelling machinery has been located in the space beneath the car floor, with the result that it is no longer necessary to devote a section of the car space to this purpose, but practically the entire length of the body is available for passenger accommodation.

Breakdowns of trains occur at times in tunnels, and a particularly troublesome kind are those caused by defective insulation, either of conductor rails or of train equipment. Although there is an almost entire absence of combustible material in the trains, the fumes caused by burning insulation, having no outlet, may spread rapidly through the tunnels and alarm the passengers. A pair of bare telephone wires is therefore carried through each tube tunnel, and in any serious emergency the pinching of these together automatically operates a cut-out at the electrical sub-station, cutting off the current from the conductor rails, so that the passengers can, if necessary, walk without risk along the track through the tunnel to the nearest station.

Breakdowns in lifts are specially guarded against. For the most part lifts are installed in pairs in the same shaft, and if a defect develops in the operating mechanism of one lift, the second lift is

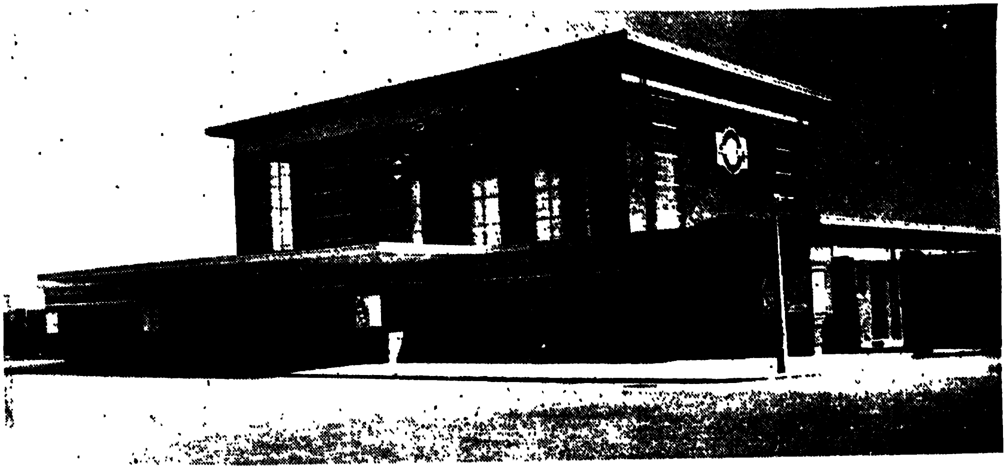


PLAN OF AN EXTRACTION FAN HOUSE

Fig. 16. This plan shows the importance and extent of the ventilation system of a tube railway—the actual tube being at left. The air in tubes is actually more healthy than the average outside atmosphere, and the health of tube staff employed permanently underground has been proved good.

lowered and the passengers transferred.

Ventilation of this great underground tube system is a matter of primary importance (Fig. 16). Its principal purpose is that of keeping down temperature, for by way of friction of various kinds the electrical energy used for working the trains is converted into heat, and there is also the smaller warmth radiated from passengers also to be reckoned with. A good example of modern tube



MODERN TYPE OF UNDERGROUND STATION—I

Above is a characteristic modern station of London's underground, Enfield West. Architectural design strictly adapted to purpose has been greatly developed. Large metal windows set in the brickwork without frames supply excellent natural lighting. Stations of this type sometimes have a tower to prevent a rush of air along the platforms and also act as a vantage point.

ventilating methods is found in the four and a half miles of tunnels from Finsbury Park to north of Bounds Green, on the Piccadilly tube, which has three 12 ft. diameter ventilating shafts.

At the surface level rotary fans are installed, running at 480 revs. per minute, in pairs, each fan being capable of extracting at 70,000 cub. ft. per minute; one runs continuously, and the other is put into commission as necessary to keep the tube temperature at a predetermined level. Separate local ventilation is provided for the station platforms by branches from the main duct; and assistance is given in the tunnels by the movement of the trains themselves. The velocity of the air used in ventilating is arranged not to exceed 1,200 ft. per minute. The air in the tubes is very dry, and so is unfavourable to bacteria, while the slight production of ozone by the electrical apparatus also acts to some extent as a germicide. Actually the health of the tube staff employed permanently underground is very good.

MODERN TYPE OF UNDERGROUND STATION—2

This is the station at Southgate, showing how design is adapted to fit into a town planning scheme

STAMP CANCELLING BY MACHINE

Fig. 1. When letters have been sorted according to size, stamp cancelling is done by machine swiftly and clearly. The machine turns out 600 letters a minute, each with a sharp imprint.

WHAT HAPPENS WHEN YOU POST A LETTER

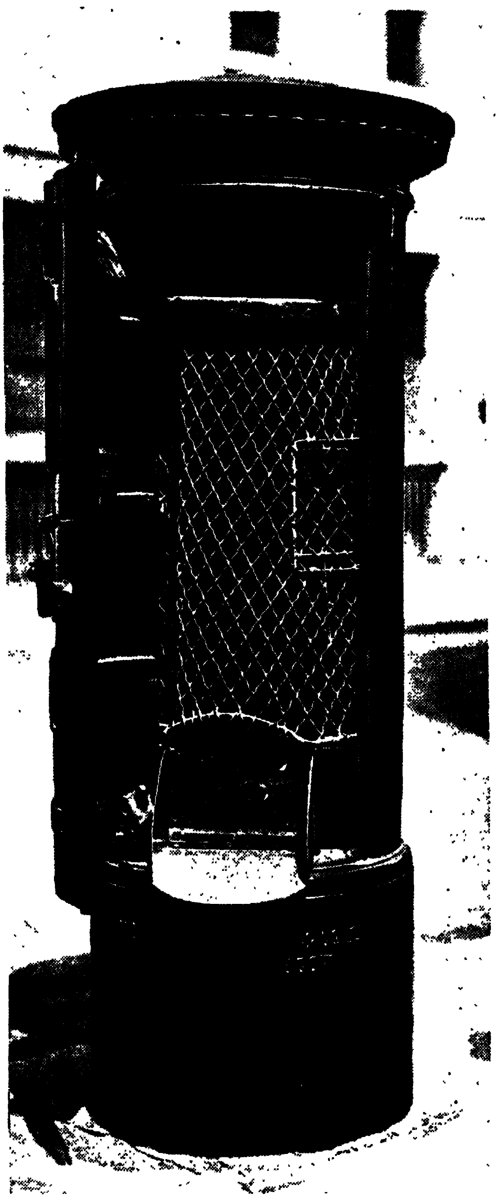
Stamp cancelling. Sorting processes—primary and secondary. The circulating list. The blind division. Care of registered letters. How mail-bags are secured. The post office railway. The travelling post office. Picking up and dropping mail at speed. Sorting before delivery. Dealing with foreign mail.

ALTHOUGH there can be few people who do not write letters, there are not many who can tell you just what does happen to their letters after they have been dropped into one of the 88,000 pillar boxes or posted at one of the 25,000 post offices in Great Britain.

Let us trace the course of a letter posted, say, somewhere close to Maldon, Essex, and addressed to someone living in Aberdeen. This letter will be only one of more than 25,000,000 that will be handled by the post office during the day. To deal with this mass of correspondence the G.P.O. employs an army of skilled sorters, another army of 80,000 postmen, many railway trains and a fleet of 8,000 motor vehicles. Our letter will not remain long in the pillar box; it will be quickly collected and taken to the sorting office attached to a head post office. Here the first operation is to separate the correspondence into three classes. Envelopes of the more general size form one class, larger covers another class, and the third includes newspapers and bulkier packets. The letters are arranged so that the addresses all face one way, after which they are carried off to another part of the office for stamp cancelling. At one time all date stamping was done by hand, as it still is in numerous small offices, but in offices with considerable postings electrical stamping machines have been installed. Previously a team of hand stampers was required, and an expert stamper could keep up a steady rate of 100 letters a minute, but the machine has nearly everywhere replaced the team. As it is fed with the faced-up letters it throws them out on the opposite side at the rate of 600 a minute with a clear imprint of the date and definite cancellation of the stamp (Fig. 1). The machine also records the number of letters passing through it, thus giving a valuable indication of the amount of traffic which is being handled.

From the machines the letters are transferred to the primary sorting tables—the first sorting process. On these tables are frames containing forty-eight boxes (Fig. 2). Each box holds about fifty letters, and provides for what is known as a sorting selection. The names of the selections are written boldly on metal fillets, and the boxes are arranged so that those for which there are the most items come in the centre, thus economizing the physical movements of the sorters.

Above each sorting fitting is a framed circulation list which is hung at an angle convenient for reference. These lists are arranged so that the number of entries to be memorized by the staff is reduced to a minimum. The lists show the general circulation of the correspondence, and the general list is followed by the exceptions to the rules (Fig. 3).



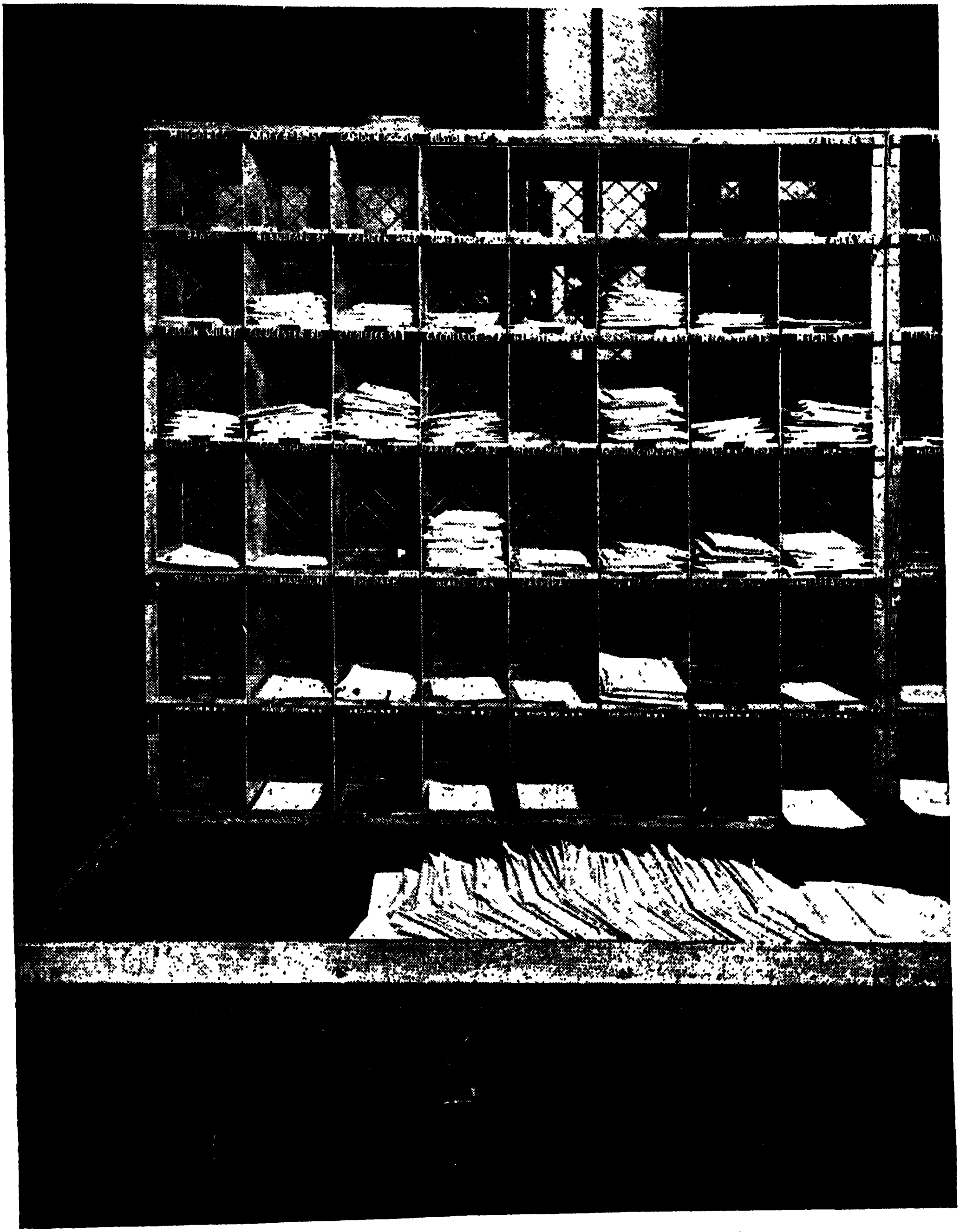
INTERIOR OF A LETTER BOX

This is how the letter box looks after being cleared, the mail passing through the chute.

It is during the primary sorting process that letters bearing insufficient postage or indecipherable addresses are dealt with. A postage due label for double the amount of the shortage is placed on the offending letter (the extra charge is a fine for the trouble and expense incurred) and a note is made to ensure that the sum is in due course received at the office to balance the use of the stamp. Each sorting office has a blind division which has to tackle the deciphering of bad writing and the solving of wrongly addressed correspondence. At one time many people amused themselves by sending letters with puzzle addresses to see whether they could beat this section of the post office, and hours were spent by the staff working out such problems. But regulations have been changed, and, unless a solution can be found quickly, the letter is returned to its sender as insufficiently addressed. Bad writing causes but little trouble to the staff, which handles so much correspondence that even the worst scribble is read at a glance. Other tasks of the blind division are to reseal correspondence that has opened in transit, and to repack parcels that have become loose.

When an undeliverable letter bears on its outside the name and address of the sender it is returned direct. Otherwise, it is opened and returned to the sender, or, if the correct address is shown inside, sent on to the addressee. If it cannot be disposed of in this way, and it contains any enclosure of importance, it is held in a Returned Letter Branch pending possible application. Articles found loose in the post are dealt with on similar lines. Undeliverable postcards and circulars are destroyed unless they bear a request for their return to senders. Many perishable articles have to be destroyed immediately, while others are kept in a cool room while their owners are being traced. Jewellery and other items of value are carefully marked and stored away to await being claimed.

An important part of every sorting office is the enclosure where registered letters are dealt with. No officer may enter this section unless he is on registered letter duty. Each officer working in



FRAMES USED IN THE FIRST SORTING PROCESS

Fig. 2. From the stamp cancellation section the letters are transferred to the primary sorting tables—the first sorting process. On these tables are frames containing forty-eight boxes. Each box holds about fifty letters and provides for what is known as a sorting selection. The names of the selections are written boldly on metal fillets and the boxes are arranged so that those with the most items come in the centre, thus economizing the physical movements of the sorters. The above photograph illustrates a frame of forty-eight boxes in a northern district of London, and is reproduced on a sufficiently large scale to show the way in which addresses are classified. At this stage letters bearing insufficient postage or indecipherable addresses are dealt with.

PRIMARY SORTING IN PROGRESS

Fig. 3. Above each sorting fitting is a framed circulation list hung at an angle convenient for reference. These lists are arranged so that the number of entries to be memorized by the staff is reduced to a minimum. They show the general circulation of correspondence, also exceptions.

the enclosure has a separate lock-up fitting with a sliding front which locks automatically when closed (Fig. 4). Registered items are passed forward under a system of transfer against signature from the time when they are accepted over a post office counter until the delivery receipt forms have been signed and delivery has been effected.

The inland sorting is built up on a county basis, and it is of great assistance to the department if the name of the post town and its county are shown on all inland postal packets. Some of the sorting boxes are labelled for single towns, and the selections for these places, known as direct selections, require no further sorting before dispatch to another office. But it is, of course, impossible for every sorting office to dispatch direct mails to every single place, or even to make up bundles of letters for every delivery office throughout the country. Apart from those for the larger places, therefore, letters are sorted into county groups, and have to be sorted at least once again before being sent off to their destinations.

The subdivision during the secondary sorting is more detailed, but letters for the smaller places are still not separated unless their destination is in the same locality as the sorting office in which the work is being performed. The plan is to send correspondence for a particular area to one large office in each district, known as a distributing centre. Mails come from all over the country to these distributing offices, which make up bags of correspondence for even the

smallest places in their own districts.

Even in the modern sorting office with its many devices for saving seconds there is a link with the past. Some of the sorting boxes are labelled Road—the Irish Road, the South Road, the West Road, the Scotch Road. The word has come down from the days of John Palmer, the Bath theatre proprietor, who sponsored the mail-coach system, and whose first coach ran from Bristol to London on August 2, 1784, covering the distance in seventeen hours—a remarkable speed for those days.

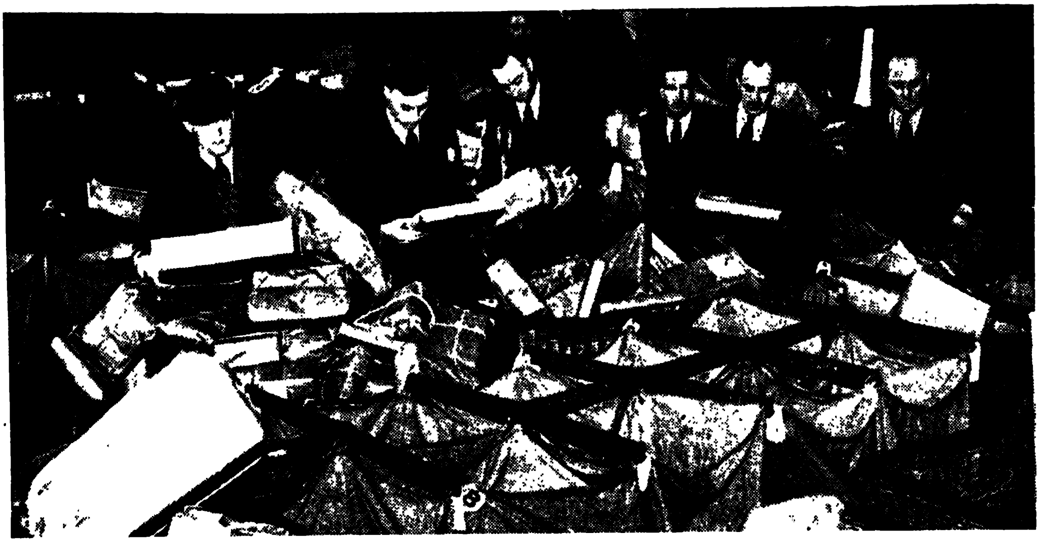
To return to our letter: Maldon would not have sufficient correspondence to justify sending direct mail to Aberdeen, so it is placed in the Scotch Road box, and later tied in a bundle with other letters also going north of the Tweed, and put into a bag that is being sent off to headquarters at Mount Pleasant in London for further treatment.

When each bag is filled it is sealed. At one time all bags were sealed with wax before dispatch, but nowadays lead seals are in universal use. They are threaded on a string with which the neck of the bag is tied, and when crushed by a hand press, cannot be tampered with or removed without cutting the string (Fig. 5). At the bag-opening stage the used lead seals are preserved and returned to store where they are melted and eventually reissued.

The mail is taken to the railway by motor van and sent on its way to London. At Liverpool Street Station, however, there will be no vans waiting to carry it to its next sorting office, Mount

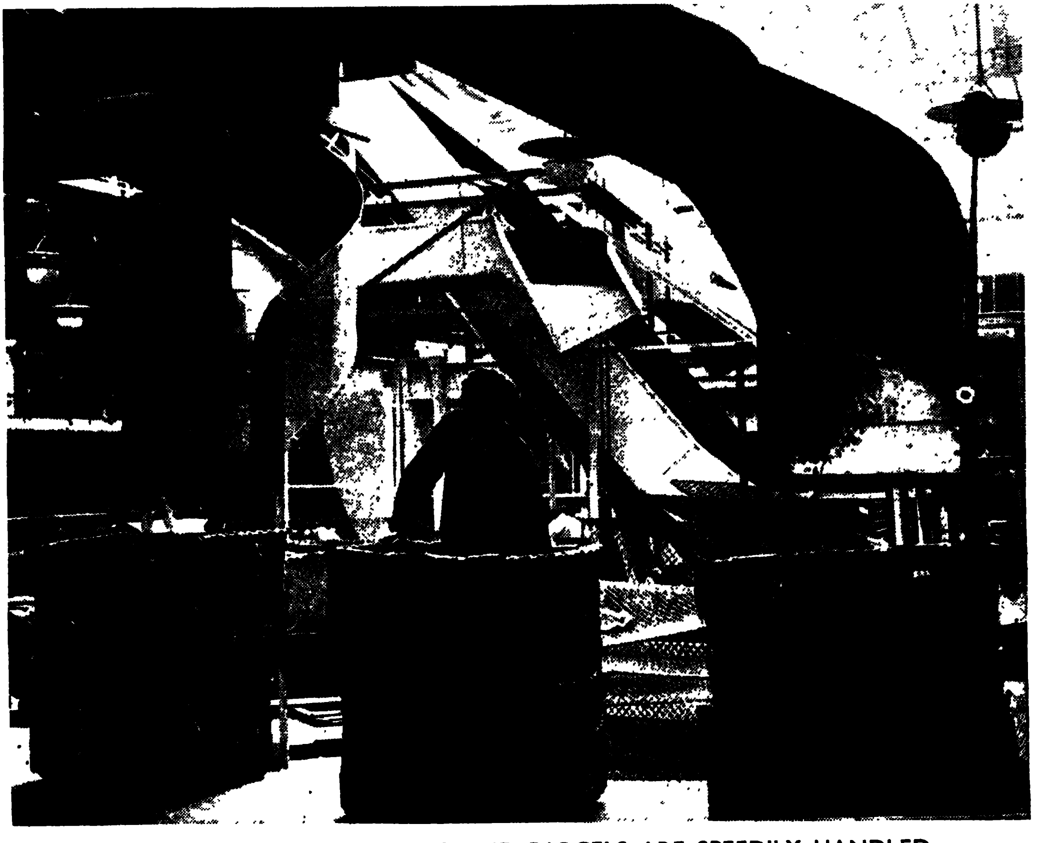
SYSTEMATIC HANDLING OF REGISTERED MAIL

Fig. 4. Registered letters are dealt with in a special enclosure with separate lock-up fitting and sliding front with automatic lock. Items are passed forward under a system of transfer against signature from the time when they are accepted until the delivery receipt forms are signed.



SORTING CHRISTMAS PARCELS

Parcels are sorted in the same fashion as letters, but into large bins as shown above. Packages that have become loose or opened in transit are repacked, while insufficient addressing and careless handwriting do not present much difficulty to the G.P.O.'s army of skilled sorters.



CHUTES BY WHICH LETTERS AND PARCELS ARE SPEEDILY HANDLED

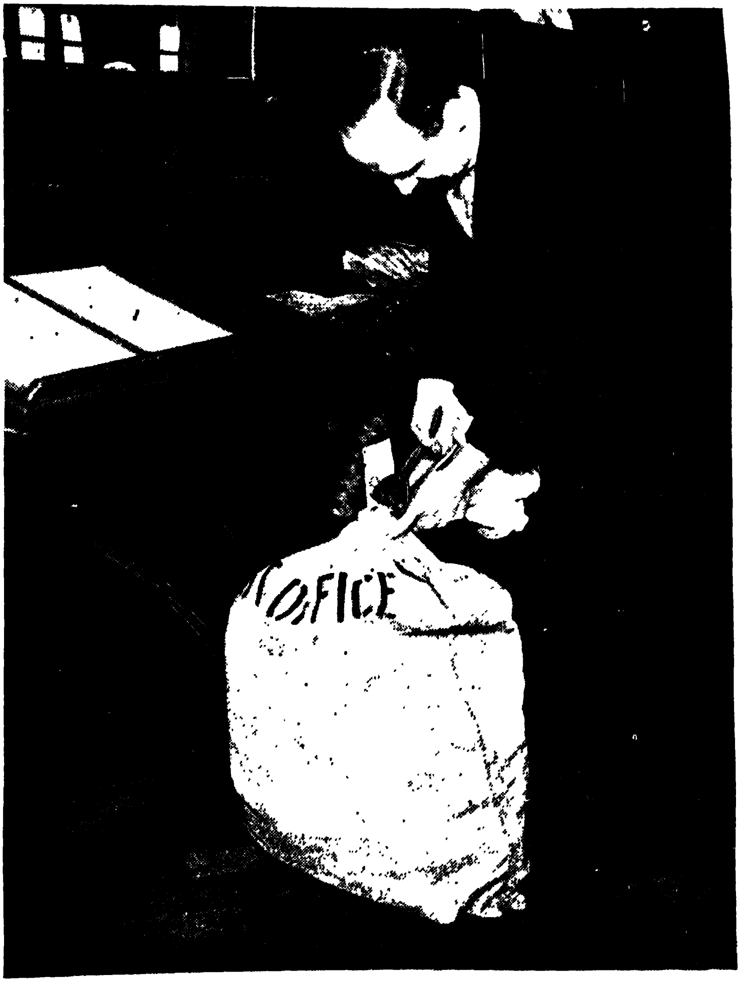
The process of sorting is simplified and made speedier by the use of chutes of this type.

Pleasant, for under this terminus the post office has one of the stations of its own railway for the transport of mails. It is the only postal railway of its kind in the world, and, although it was completed in 1927, its existence is still unknown to many Londoners (Fig. 6).

THE POST OFFICE RAILWAY

In the course of one year more than ten million bags of mail are transported on this railway, and the trains run more than 1,700,000 miles. It is six and a half miles long: the trains carry no drivers and are electrically controlled from a central point (Fig. 6). Every sixty minutes forty trains travelling at a speed of 35 m.p.h. 80 ft. below street level, pass under several passenger tubes, from the Eastern District Office in Whitechapel to Paddington (Fig. 7). There are intermediate stations at Liverpool Street, King Edward Building (the concentration office for foreign letters and the delivery office for the City), Mount Pleasant, the West Central and Western District Offices, and the Western Parcel Office where the parcels for the West End are dealt with. The station platforms are not unlike those of the passenger tube railway stations. The one at Mount Pleasant is the longest (313 ft.) and that at the Western District Office (90 ft.) the shortest.

The man-handling of bags has been reduced to a minimum. Each station is equipped with lifts and spiral chutes, and several have in addition moving band conveyors and bag elevators. As the bags are made up in the sorting offices above ground they are passed by chute direct to the railway platforms and wheeled in containers to the trains.



SEALING THE MAIL-BAGS

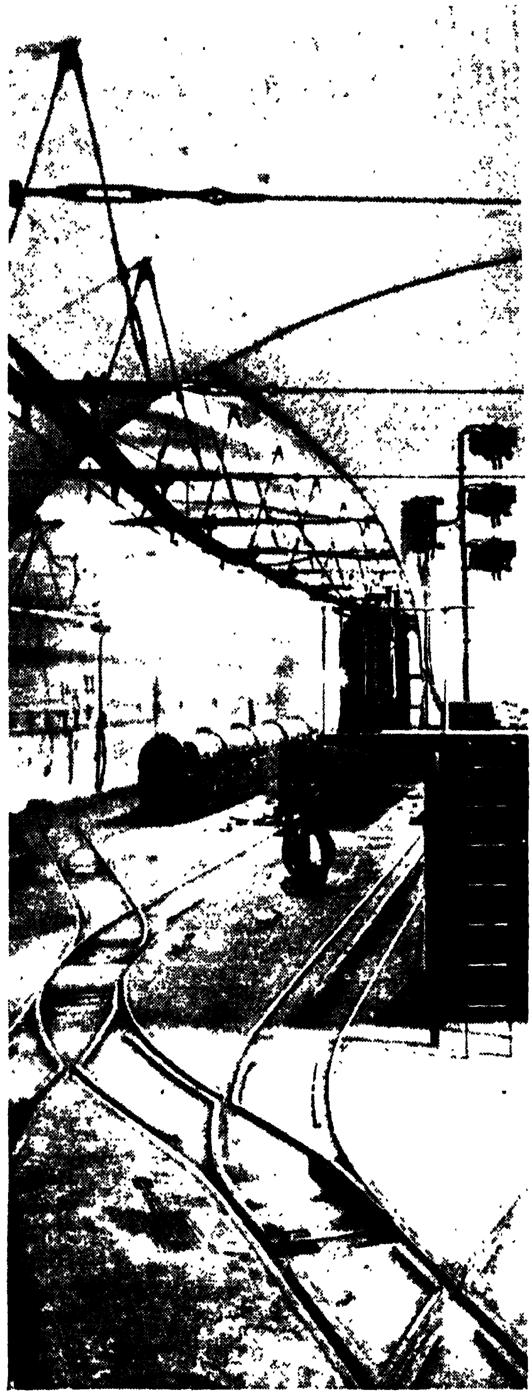
Fig. 5. Each mail-bag is sealed with a lead seal, threaded on the string with which the neck of the bag is tied. When crushed by a hand press the seal cannot be tampered with without cutting the string.

DIRECTING UNDERGROUND POSTAL TRAFFIC

Fig. 6. Trains which carry no drivers are electrically controlled from a central point.

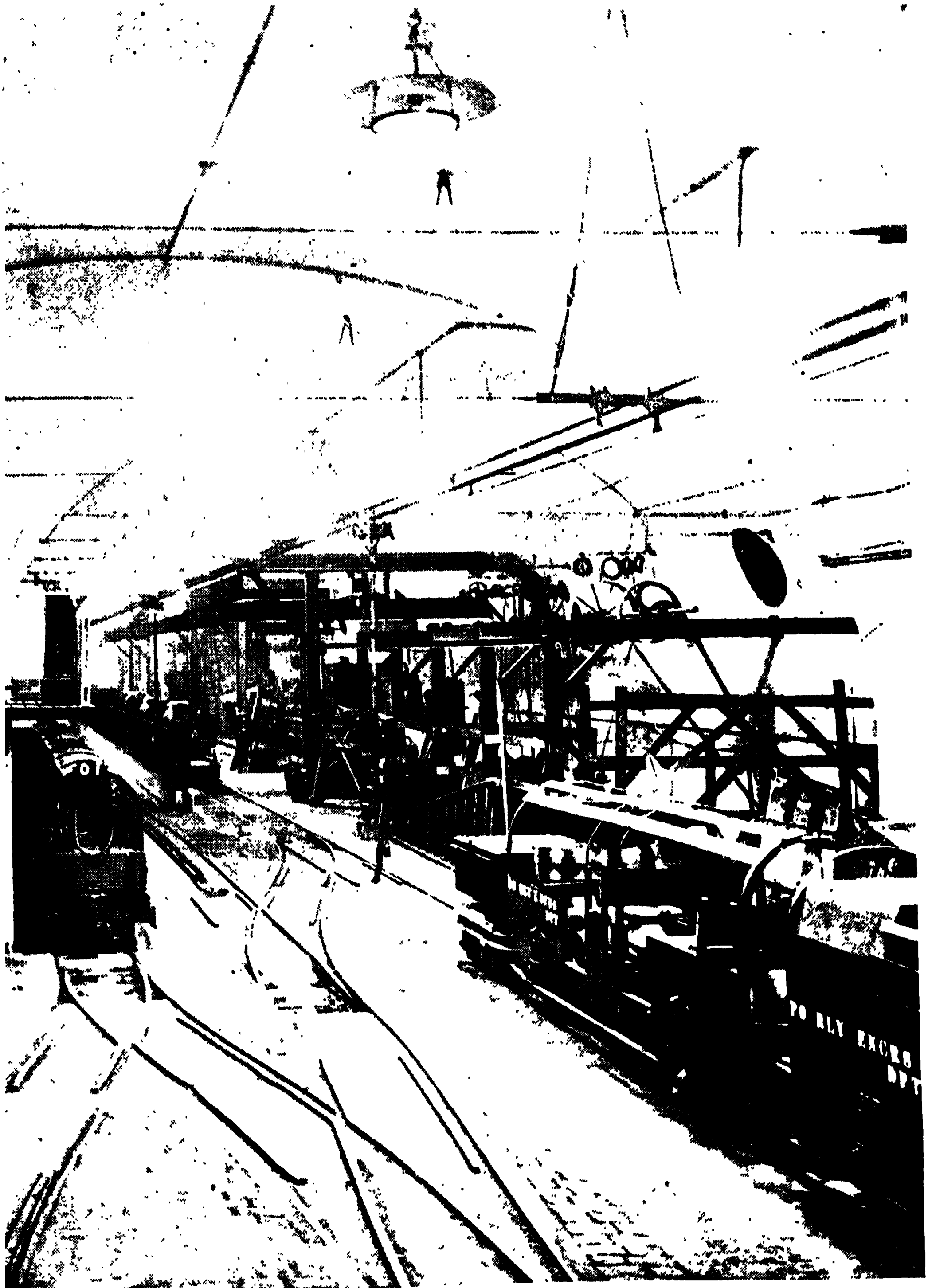
Mail-bags unloaded from the trains are wheeled into lifts or on to conveyors and carried to the bag elevators and so to the above-ground sorting offices (Fig. 10). As soon as the bags tumble off the escalators they are taken by bag-openers, who examine the label and seal of each bag to see that they are correct and intact before they open the sacks. Each mail contains a letter bill on which are entered particulars of the number of bags which that particular mail contains and of the registered and express letters it carries. As soon as the bag opener is satisfied that all is correct he distributes the various bundles to the different sorting divisions. All the bundles are labelled, either with the name of the sorting division in which they are to undergo further treatment, or with the place-name of destination. These latter will be dispatched direct.

At most of the larger offices electric

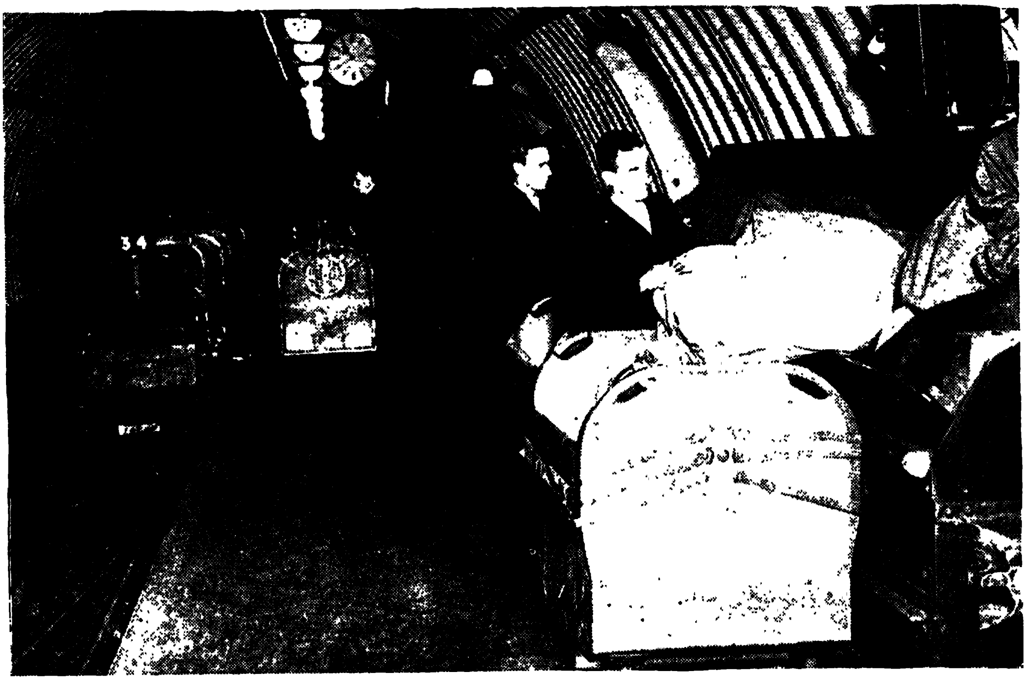


FORTY OF THESE POSTAL

Fig. 7. Millions of mail-bags are transported yearly by the Post Office Railway, forty trains

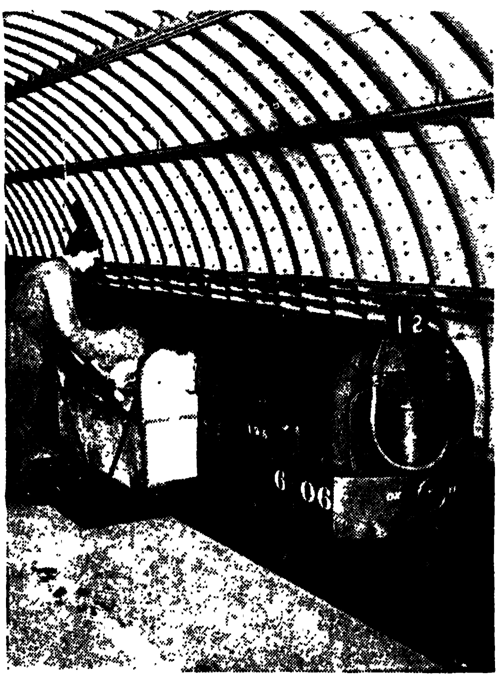


TRAINS PASS EVERY HOUR BENEATH THE PASSENGER TUBE
passing hourly beneath the passenger tubes. These trains travel at a speed of 35 m.p.h.
80 ft. below street level, between the Eastern District Office in Whitechapel, and Paddington



PUTTING MAIL-BAGS IN CONTAINERS AT AN UNDERGROUND STATION

Fig. 8. The bags are passed by chute to the platform which is not unlike the usual passenger station.



LOADING THE TRAIN

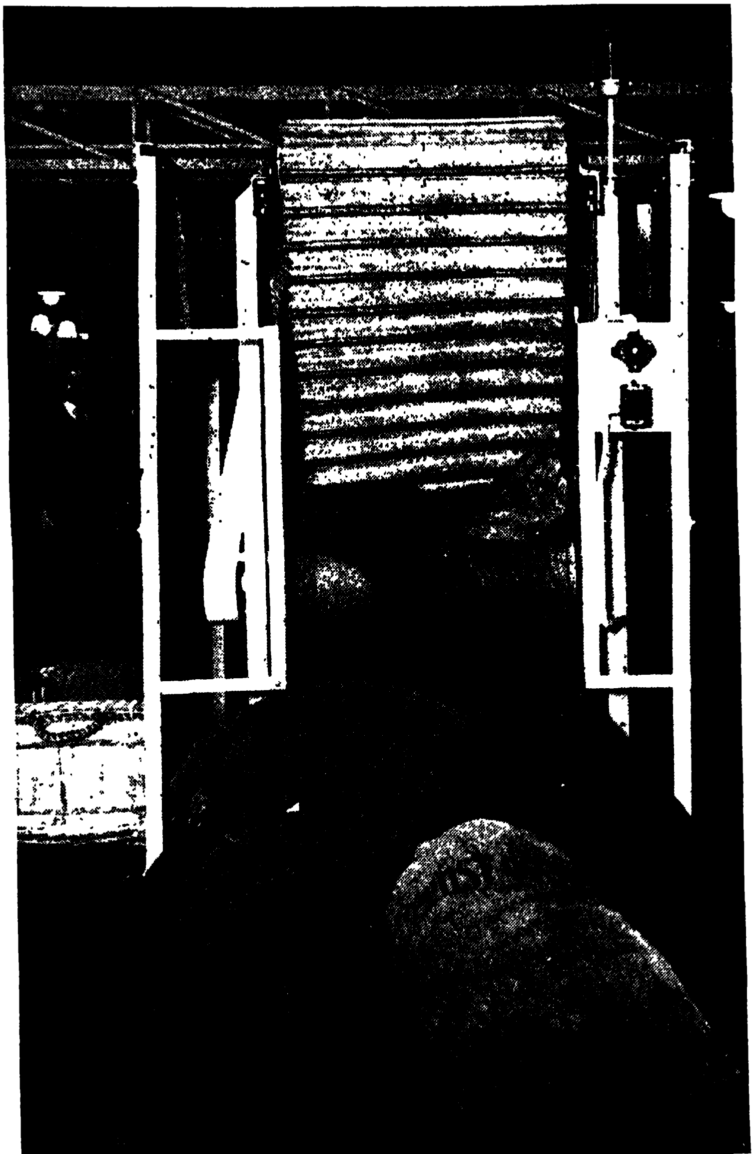
Fig. 9. The containers are packed with mail-bags and wheeled into the train, as shown.

conveyor bands are used to transport correspondence from the bag-opening tables to the divisions. Seconds matter, for mails are leaving all the time, and with some letters the interval between their arrival and the sending off of the mail with which they connect is short.

If the letter to Aberdeen had been posted early in the day—as it should have been if at all possible—its secondary sorting stage can be fitted in now.

Mount Pleasant is the hub of Britain's postal service, and is the largest sorting office in the Empire. Every day it deals with 4,000,000 letters and makes up 4,000 separate dispatches of mails. The Inland Section at the Mount deals with letters for the provinces received in mails from abroad, and with those passing in transit from one provincial district to another where the route through London is convenient. Mails arrive or leave almost every five minutes throughout the day and night, for this

office never closes its doors. There is a staff of over 3,300, covering attendances during the twenty-four hours, seven days of the week the whole year round. The mail for Aberdeen leaves Euston every night on the most famous of all post office trains—the Down Special Travelling Post Office, which, with its companion train the Up Special (Aberdeen to London), is the largest T.P.O. in the world devoted entirely to post office business. The T.P.O. was first visualized in 1826 by Sir Rowland Hill, whose name is associated with many postal innovations beside the Penny Post. In 1838 the first travelling post office ran from Birmingham to Liverpool along the Grand Junction Railway. It consisted of a horse box with a few wooden shelves for the sorting of letters. The experiment was a great success, and within a year a specially constructed sorting carriage, 16 ft. long, was built by the railway company. Even at that early date it was equipped with apparatus for picking up and dispatching mails while the train was in motion. The Down Special is a lineal descendant of the horse box of 1838. First introduced in 1885, for fifty-five years it has left London for Scotland every night at the same time with the sole exception of Christmas nights. During that time it has grown steadily in size and importance, and now consists of twelve carriages, of which five



CONVEYING THE MAIL-BAGS BY ELEVATOR

Fig. 10. The bags go to the above-ground sorting office by escalators, and the label and seal of each are examined to see that they are intact.

SORTING MAIL IN THE TRAVELLING POST OFFICE

Fig. 11. When the Down Special pulls out of Euston Station there are fifty sorters on board with some 150,000 letters to sort on the journey, 1,300 bags of mail to discharge at intermediate stations. One side of the carriage is entirely occupied by the sorting racks as here seen.

are used for sorting, six for the stowage of mails and one for the receipt and dispatch of bags by railside apparatus.

When the train pulls out of Euston there are fifty sorters on board with not less than 150,000 letters to sort on the journey, as well as 1,300 bags of mail to discharge at intermediate stations. The first impression the stranger receives of the interior of a travelling post office is that of orderly disorder. A floor strewn with bags; tables piled high with letters and newspapers; sacks here; labels, string, route books and lead seals, official forms, date stamps there. One side of the carriage is entirely occupied with sorting racks. Opposite are rows upon rows of iron pegs from which hang labelled bags in serried ranks (Fig. 11). Here also hang the fire extinguishers and the alarm cords. Within the limited space everything possible has been done for the comfort of the staff. Rope mats cover the floor, and green felt curtains at the windows check the draught cutting in at the doors. There are heated pipes in the roof, and racks for personal belongings. Steam puffs cosily from a copper kettle which is boiling on an electric stove.

There are two openings for apparatus working: one controlling the metal arm from which hang the delivery pouches, the other for the net that gathers up the incoming mail in this fascinating game of give and take. The device used owes

PICKING UP MAIL AT 60 MILES PER HOUR
Fig. 12. The bag is strapped in a leather pouch and hangs from an iron standard. A V-shaped grip on the carriage net catches the strap of the pouch, releasing it from the standard and causing it to fall into the net, whence it rebounds into the sorting carriage. The angle of the net is arranged to minimize the force of the impact.

its invention to the early struggles of the railway to win passengers and merchandise from the road coaches. Its superior speed was its greatest asset, but to secure this speed increase (for the first trains ran only at horse-coach rate) stops had to be cut out, and the post office was faced with the problem of setting down and picking up bags from a non-stop train. It says much for the forethought of the apparatus pioneers that little change from the original method has been necessary. Bags used in this part of the work are marked with a load line, restricting the weight of the mails to 30 lb. Each bag is strapped up in a leather pouch weighing 20 lb., and the whole is suspended from an iron standard by the wayside. The carriage net is fitted with a V-shaped grip that catches the thick leather strap of the pouch, releasing it from the standard and causing it to fall into the net, from which it rebounds into the sorting carriage (Fig. 12). The angle of the net is cunningly arranged to minimize the force of the impact between the pouch and the carriage floor. When mails are dropped from the train the pouches are hung on an arm, and are caught in a net by the wayside. The arm is fitted with a powerful spring so that when the pouch is removed the arm flies back to the perpendicular (Figs. 13 and 14). Immediately the incoming pouch enters the carriage it is opened, and the bags extracted and taken to the sorting table, where the contents are dealt with, travelling all the while towards their destination at a mile a minute.

Normally, familiar sights along the line tell of the time when the apparatus has to be made ready. But in fog the staff depend on sound alone to indicate position. The soft purr of going along

DELIVERY OF A MAIL-BAG
Fig. 13. When mails are dropped from the train the pouches are hung on a metal arm and are caught in a net by the side of the track.

an embankment, the growling snarl of a passing bridge, the rumble of a culvert and the hoarse roar of a wayside halt are all unfailing signposts that tell these experienced travellers that the Scotch border is approaching, that Perth has just been passed, or that it is time to put the apparatus out for the last collection and delivery of the trip.

THE SORTING CARRIAGE

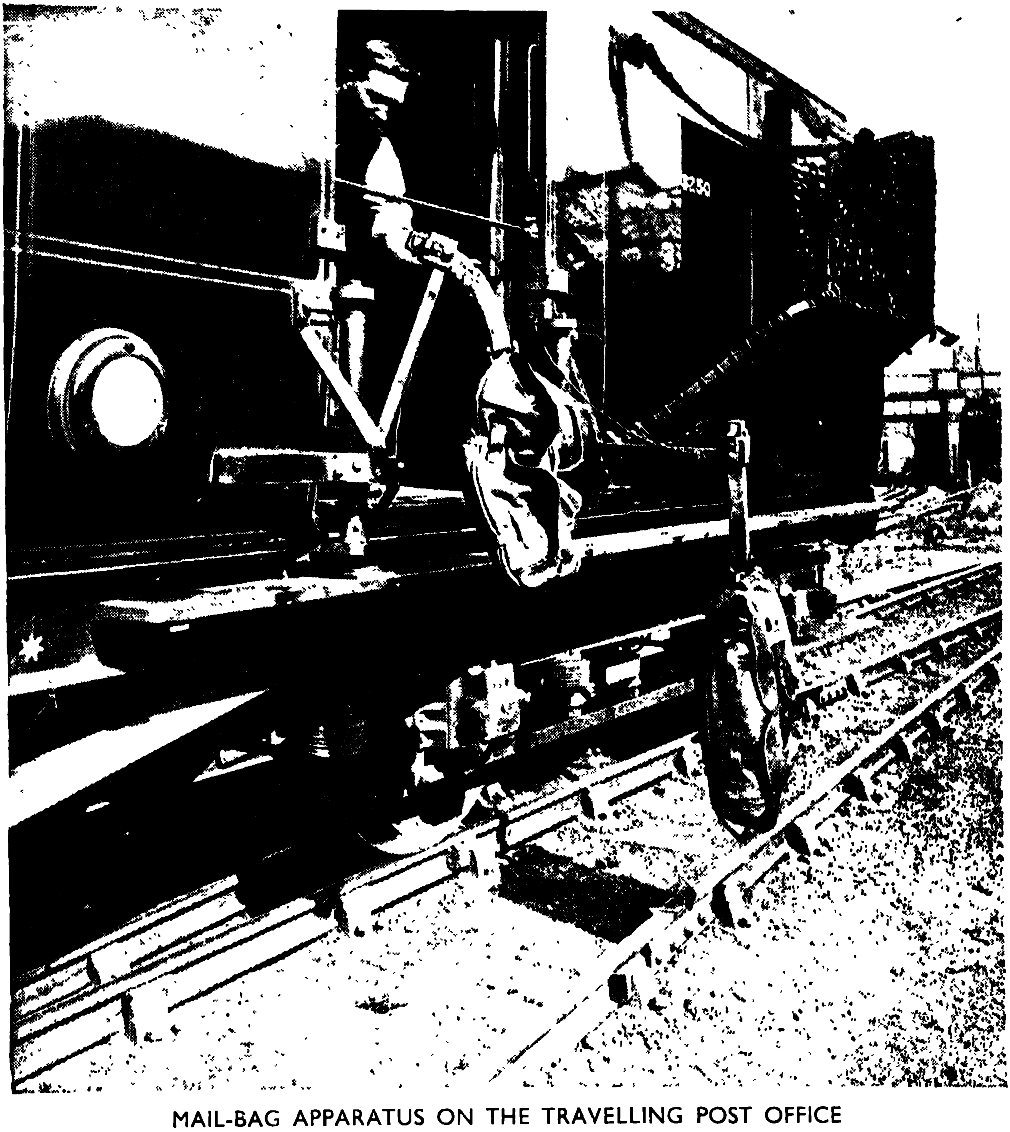
Each of the sorting carriages deals with a particular division of the country, and offices sending mail to the travelling post offices sort according to these divisions so that the bags on receipt can be taken direct to their proper vans. Mails are dropped and picked up at so many points that on the specials two men are employed exclusively on this work. There is one point on the down run where a bag is received by apparatus, a portion of the correspondence it contains withdrawn, enclosed in another bag and dispatched by apparatus within three minutes. A delay of seconds in any of the operations, and the dispatching point would be passed—but the job is done night after night without hitch. Crewe is the pivot of this balanced postal machine. Here the minor T.P.O.s are waiting to be fed, for this is the night mail centre of the country, and a large number of important mail trains are timed to meet here and give connexions with each other. Between midnight and 3 a.m. thirteen T.P.O.s enter and leave Crewe station, including night mails to and from Scotland, the up and down Irish Mails, and those mail trains working to Holyhead, Shrewsbury, Cardiff, Birmingham and York.

Letters reach Aberdeen in less time than is taken by the fastest passenger trains, in spite of the fact that eight stops are made on the way. The city is reached at 7.52 a.m., when a van is ready to take the letters to the local sorting office for yet another stage of treatment. The inward sorting has now to take place, and letters have still to be handled at least twice before they leave in a postman's pouch for delivery.

Correspondence has been piling up at delivery offices all through the night for distribution by the first post. Some of the letters have been posted only a short distance away, others have travelled hundreds of miles in this country, others again come from the ends of the earth. None of them perhaps has had exactly the same treatment as any other during the previous stages of its journey, but all must now undergo exactly the same sorting process before delivery. In each town every postman has his individual delivery area, called his walk. After the bags of correspondence received by rail, road, sea or air have been emptied, the first process is to divide the letters into yet another 48-box fitting, this time labelled with the names of these walks or of the village delivery offices which take their part in disposing of the letters. The postman takes the letters for his walk from the sorting boxes and makes a further subdivision. His route has been carefully drawn up to avoid unnecessary walking, and he arranges the correspondence according to this plan and ties the letters into convenient bundles. Then out they go on the last part of their journey, to be dropped into the addressee's letter box.

FOREIGN MAIL

Letters to and from countries abroad are dealt with at King Edward Building, the great block of postal offices situated in Newgate Street, London. In normal times mails are received and distributed here at all hours of the day and night. Dispatches to the Continent are made several times a day, while those for extra-European destinations are sent off at less frequent intervals, dependent

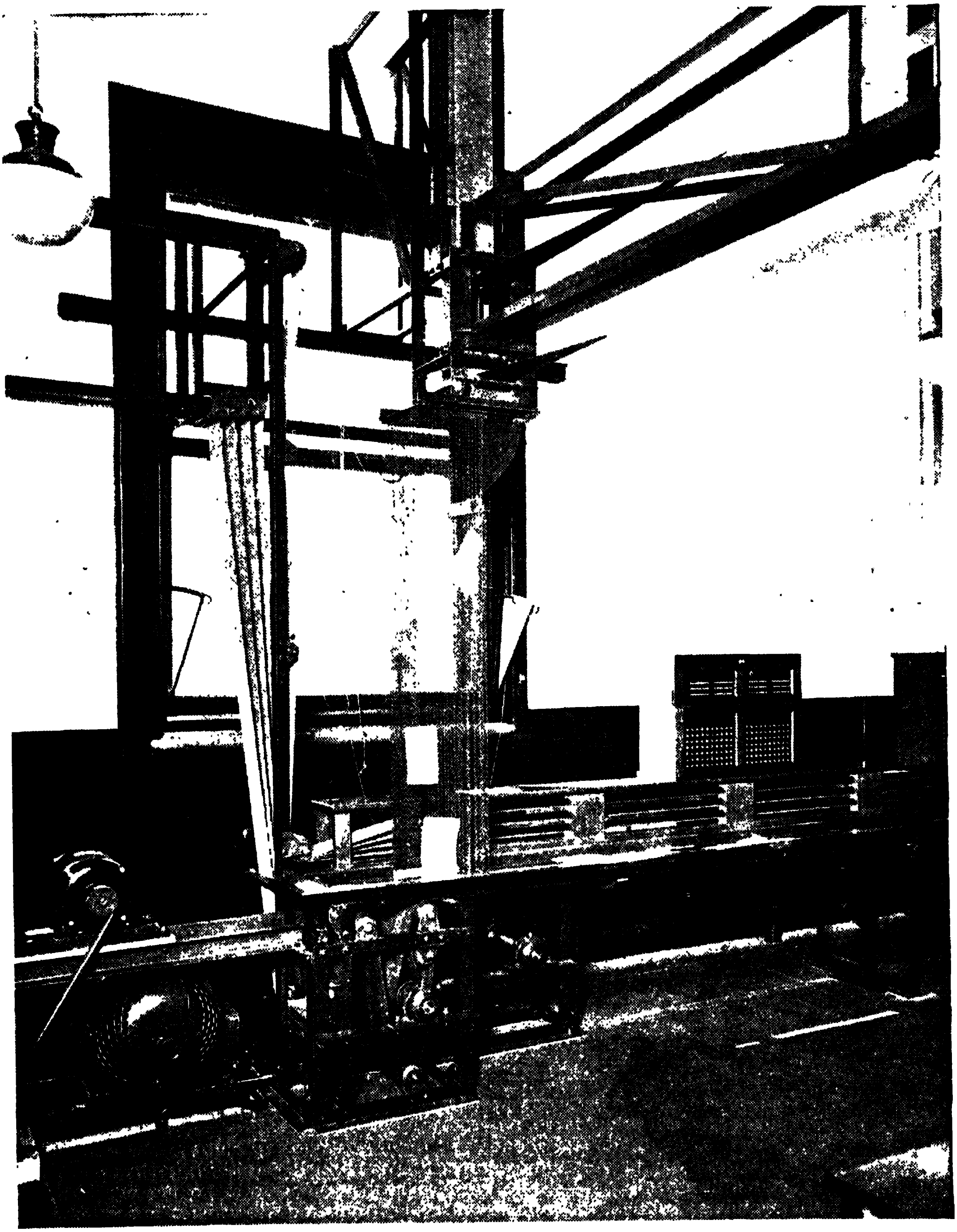


MAIL-BAG APPARATUS ON THE TRAVELLING POST OFFICE

Fig. 14. This photograph shows clearly the arm by which the pouches are dropped from the train. It is fitted with a powerful spring so that when the pouch is removed it flies back to the perpendicular.

upon the sailing times of the various steamships. In the case of the heaviest mails (such as those for the Far East, South Africa, the U.S.A. and Canada) the bags are dispatched to the port of embarkation almost daily as they become available. As the time draws nearer to the final dispatch the pressure on the departure platforms at King Edward Building increases, and the chutes from the sorting office are delivering constant streams of bags to the loading teams who are transferring them to the waiting vans.

Trains bringing in the incoming mails are met at the stations by sorters and porters from the Foreign Section who separate the bags for their various destinations in the city or provinces. Nearly one thousand loaded vans enter and leave the yard of King Edward Building every twenty-four hours.



CHAIN CONVEYER WHICH TAKES TELEGRAMS TO THE TELEPRINTER

The development of telegraphy has been marked by continuous mechanical improvement. Hand sending by means of the Morse code is laborious and so an electrical typewriter was developed to a point where it could be connected with a telephone line and operated by a typist. Telegrams from the smaller offices are dictated over the telephone to a phonogram position where they are typed and put on to a moving conveyer band of the kind illustrated above. This takes the telegram to the teleprinter position. Telegrams dictated by private telephone users are dealt with in a similar fashion. In this way the telephone user is able to send telegrams at any hour of the day or night and to be independent of the local telegraph office. Much time is thus saved.

WHAT HAPPENS WHEN YOU SEND A TELEGRAM

Electric telegraph—a revolutionary innovation. The teleprinter. Telegraph ships. Laying submarine cables. Their maintenance and repair. Wireless telegraph stations. Picture telegraphy. Transmitting the message. The Morse code. The teleprinter code. Sending messages by telephone. Mobile telegraph.

THERE has always been a demand for a system of sending urgent messages rapidly but it is only within the past century that such a system has become available for our use. Today the means of communicating messages is so widespread that even those in the remotest parts of our islands are able to send and receive such messages. The development of electricity has made this possible. At the present day a detailed individual message can be sent from any one of 15,000 post offices, 50,000 public telephone kiosks, or 3,000,000 private telephones to any address in the United Kingdom for the small sum of ninepence.

Forgotten today is the great enthusiasm with which the electric telegraph was greeted a hundred years ago. This practically instantaneous means of communication was something new in human experience. It revolutionized all conceptions of space and time. The advent of the telephone forty years later created no such furore—it was regarded as just a special form of electric telegraph. Nor, twenty years after that, did the wireless telegraph make any great stir.

At the present time the standard telegraph instrument is an electrical typewriter, the teleprinter (Fig. 1), which, when operated, will cause similar movements by a typewriter at the distant end of a telephone line: for telegraphs no longer have separate wires but use circuits in the vast network of underground telephone cables now laid in this country. By suitable switching arrangements a teleprinter can operate many other teleprinters simultaneously at widely separated positions. The police are among those who avail themselves of this facility of broadcast messages. Underground telephone circuits are very expensive, the fullest use has to be made of them and technical developments with this end in view have resulted in a system whereby eighteen separate teleprinters simultaneously sending out messages can be accommodated on one telephone circuit.

THE SUBMARINE CABLE

One reason for the excitement with which the electric telegraph was greeted lay in the fact that islands and separated continents were no longer dependent for the interchange of information upon messages carried by boat. The submarine cable had altered all that. In 1851 England had become a part of the continent of Europe when, at the second attempt, a telegraph cable was successfully laid between the shores of Kent and the French coast. A really stupendous achievement was the linking of the Old World with the New when the giant steamship of Brunel's creation, *The Great Eastern*, laid a cable from

STANDARD TELEGRAPH INSTRUMENT—THE TELEPRINTER

Fig. 1. The teleprinter is an electrical typewriter which, when operated causes similar movements by a typewriter at the distant end of the line. By suitable switching a teleprinter can operate many others simultaneously.

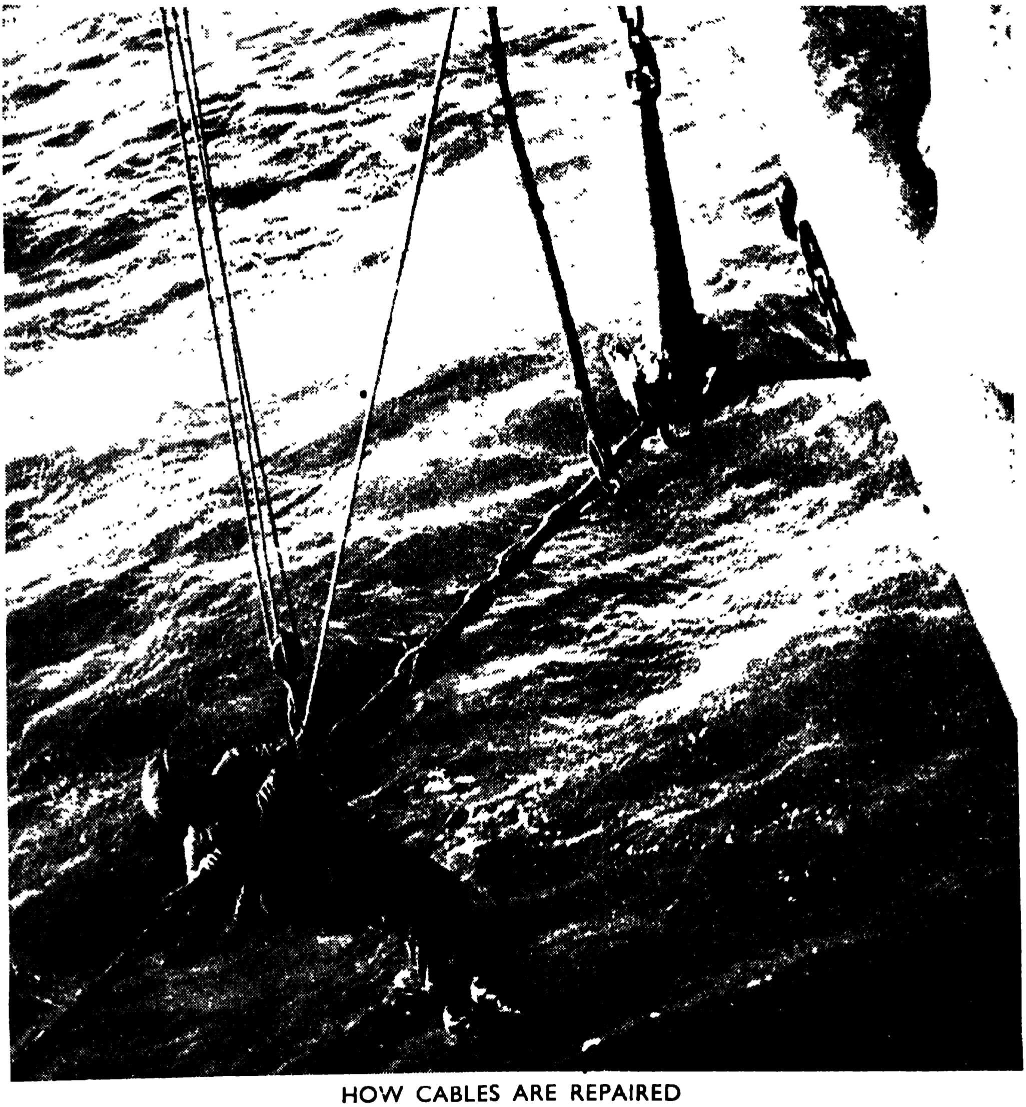
and these still carry messages without cessation day and night. There can never be too many channels of communication.

Ships have been specially designed and built to lay and maintain submarine cables (Fig. 2). The post office has a fleet of four such vessels. His Majesty's telegraph ships, as they are known, are ceaselessly patrolling the thousand miles of our coastline from which cables radiate to European countries, to Ireland and to the many islands off our coast. The job of laying a submarine cable has to be carefully

Ireland to Newfoundland in 1866. Then, with the dawn of the twentieth century, Marconi—who in his experiments had been encouraged and assisted by British post office engineers—established telegraphic communication with North America without the use of a connecting wire between the transmitting and the receiving instruments. When wireless telegraphy developed, submarine cable telegraphy was not thereby rendered obsolete, indeed, more cables were laid

planned. The cost per mile of the cable will be several hundred pounds and unnecessary deviations in its route will therefore be expensive. This route is plotted on a chart and the cable ship then steams over the route laying down a series of marking buoys by which she will later be able to steer her course when actually laying the cable. The contour of the sea bed on which the cable will lie has also to be accurately recorded so that sufficient cable is laid

to bed evenly. A record of variations in depth of the sea bed is obtained in a most ingenious way by a sounding device called the Echometer. This consists of a hammer which, under the control of regular electrical impulses, strikes an anvil in the hold of the ship. The sound of the hammer blow travels downwards to the sea bed from which it is reflected up to the ship again. At each stroke a vertically moving electrical pen touches the edge of a horizontally moving roll of paper. A radio valve detector picks up the echo of the hammer blow to cause an electric current to flow through the pen. The paper has been chemically treated so that a mark is made by the pen point as it discharges a current through the paper The distance travelled by the pen from the moment it touches the



HOW CABLES ARE REPAIRED

Fig. 2. Submarine cables are a channel of world-wide telegraphic communication .A specially constructed type of ship lays and maintains the cables. The post office has a fleet of four such vessels on regular patrol. Cable is paid out over the bow sheaves. Our photograph shows the bosun's chair used in securing the cable at the surface during the work of repair

paper to the moment it records the arrival of the echo is thus proportional to the depth of water under the ship.

The manufactured cable is hauled aboard the ship and coiled into circular tanks in her hold. The ship then proceeds towards the point where the cable will leave the shore. To land the shore end of the cable, which will be connected to a land line at a cable hut, the ship anchors as close inshore as possible and sufficient cable is then coiled on to a raft which takes it through the shallow water to be hauled to land. The ship now steams over the marked route and cable is carefully paid over the bow sheaves as she steams along until she is close to the other shore when the end of the cable is taken on to land (Fig. 3).

A great deal of the work of the post office ships is concerned with the maintenance and repair of the 300 or so cables around our coast. The approximate position of a fault is easily determined by electrical measurements made at the cable hut. A ship steams to this position which it marks with a buoy and then lowers a grapnel to drag across the line of the cable. The type of grapnel used depends upon the nature of the sea bottom; on sand and mud large-pronged grapnels will be used, while over rocks a chain equipped with hooks will be dragged. As soon as the cable is grappled the ship stops and the cable is slowly hauled to the surface where it is secured with chains by men lowered over the bows in bosun's chairs (seen in Fig. 2). Next, the loop of cable on the deck of the ship is sawn in two and each part tested, by signalling to the engineers in the cable huts, to discover on which side of the cut the cable is faulty. The end clear of faults is sealed and secured to an anchored buoy. The faulty end remains on board as the ship, slowly

PREPARING TO LAND CABLE AT THE SHORE END

Fig. 3. To land cable at the shore end the ship anchors close in shore and cable is then coiled on to a raft which takes it through the shallow water to be hauled on land. On shore the end of the cable is connected to a land line at a cable hut where positions of faults are detected.

TRANSMITTING PICTURES BY TELEGRAPHY

Fig. 4. By means of a special system, photographs, drawings, plans, etc., can be transmitted any distance. The picture is fixed to a cylinder which rotates at a uniform speed with the distant receiving apparatus. The illustration here shows how a photograph is clipped on to the drum. This wonderful development provides a dramatic link between press services in many lands.

steaming along the charted route, hauls in the cable. When the fault comes aboard the damaged portion is cut out and replaced by a new section of cable. Then the ship steams back to pick up the buoyed end to join it to the repaired cable which is returned to the sea at the point marked by the buoy.

As an addition to our Empire-wide cables, a chain of high power wireless telegraph stations to link up the British Commonwealth of Nations was planned about thirty years ago. The war of 1914-18 put a stop to this scheme with only the station at Cairo completed. Later, when this project was returned to, technical developments had made it possible to construct a number of "beam" wireless telegraph stations from which telegrams could be sent as far distant as Australia without the use of intermediate stations. At Rugby the post office constructed the most powerful wireless station in the world to give a service to the Americas and throughout the Seven Seas. The most striking feature of this station is a line of twelve huge lattice masts from which radio-telegraph transmitting aerials are suspended. These masts are by far the highest structures in Britain. Hitherto the spire of Salisbury Cathedral held pride of place but these huge masts have gone up to twice that height. At the top of their 820 ft. you are on a windy day, swung through an arc of 6 ft. as the mast responds to wind pressure. You can send a telegram to

TELEGRAPHING PICTURES OF A FOOTBALL CUP FINAL

Fig. 5. As the freshly taken photograph revolves a tiny spot of light is thrown on to the surface. This scans every part of the picture and the light variations so produced are converted into electrical currents which affect a beam of light shining on photographic paper fixed to the receiving drum

any ship on the high seas via Rugby radio. This station also sends out twice each day a time signal, controlled from Greenwich Observatory, by which ships can check their chronometers. In normal times weather forecasts and news bulletins are broadcast. The use of radio telegraphy has contributed largely to the safety of ships at sea and the telegraph signal SOS ". . . - - - . . ." is known by all who can read and write.

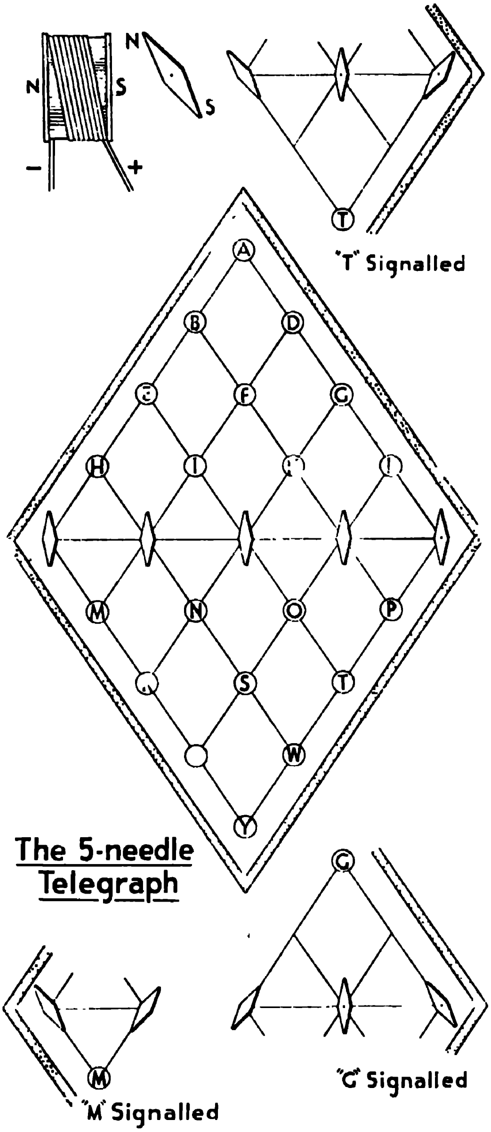
Another telegraph service which has been developed in recent years is that of picture telegraphy. By means of this system facsimile reproductions can be transmitted of such documents as photographs, drawings, plans and specifications. The picture to be transmitted is fixed to a cylinder (Fig. 4) which rotates at a uniform speed with the distant receiving apparatus. As the cylinder revolves a tiny spot of light is thrown on to the surface of the picture. This spot scans the picture with a helical movement to cover every part of the picture till the end of the cylinder has been reached. Special cells convert the light variations in the picture to electrical currents of varying intensities which affect in a similar manner a beam of light shining on photographic paper affixed to the distant receiving drum (Fig. 5). This system has also been used over wireless telegraph circuits—a picture telegraph circuit was recently set up between London and Moscow—but the high standard of reproduction in line telegraphy is not always possible when a radio circuit is used because this is liable to a measure of interference.

SENDING A MESSAGE BY MORSE CODE

Fig. 6. Telegraphic signalling is popularly associated with the dots and dashes of the Morse code which is still widely used. The Morse sending key and sounder are shown in the above illustration. Depression of the key completes an electrical circuit, operating sounder at the receiving end

Telegraph signalling consists of the transmission of electrical impulses in code form; this signalling is popularly associated with the Morse code—an arrangement of short and long impulses, dots and dashes. The Morse code is still widely used (Fig. 6) and is particularly suitable for active service conditions. These short and long impulses can be considerably distorted between the sending and receiving stations by unfavourable transmitting conditions and still be recognizable as dots and dashes. The earliest telegraphs used in this country depended not upon the duration of electrical impulses but on the movement of pivoted needles. The first to be used had five needles. These could be made to move, two at a time, to point towards a letter on the dial of the instrument (Fig. 7); the direction of their movement depending upon the direction of the current flowing. The number of needles was later reduced to two and a code of needle movements introduced. The instrument was further simplified until one needle only remained and in this form it persisted as a railway telegraph. It is still used as a railway telegraph at the present day.

In the eighteen-forties Morse instruments first appeared. These consisted of a key which could be depressed, against spring tension, by the hand of the sender to complete an electrical circuit which operated a buzzer, or other form of sounder, at the receiving station. Thus it used the Morse code, which depends on current duration rather than direction. To avoid the necessity of an operator



NEEDLE TELEGRAPH

Fig. 7. The earliest telegraphs used depended on the movement of five pivoted needles, two of which moved, two at a time, to point towards a letter on the dial. Acting as magnetic poles their direction depended on the direction of current flowing. One-needle telegraphs are not entirely obsolete and are still used on railways

always listening at the receiving instrument or losing parts of messages through some cause or other, receivers were constructed to produce a visual record in ink on a paper tape of the dots and dashes. Later developments included machines which could translate received Morse code signals to ordinary roman characters; the tape on which these appeared could be directly stuck on to a telegraph form for delivery.

Hand-sending is laborious and a skilled telegraphist is unable to transmit for any length of time at more than thirty words a minute, automatic transmitters were therefore brought into use on busy circuits. A number of telegraphists could then be employed punching holes, representing dots and dashes, on paper tape later to be fed into a transmitting machine to send Morse impulses at the rate of several hundred words a minute. These systems had drawbacks and so the teleprinter was improved till it had reached the stage where it could be connected with a telephone line and operated by a typist. This machine used a code different from the Morse code. On the teleprinter each letter takes exactly the same time to transmit whereas with the Morse code, for instance, O—three dashes—will take relatively much longer than E —one dot. The teleprinter code consists of a series of five impulses, of two kinds —marking or spacing—for each letter; preceded in each case by one spacing and ended by one marking impulse (Fig. 8). The operator finds that better speeds than those on an ordinary typewriter can be kept with less fatigue because the key movement is very short and capital letters only are used. At all the main post office telegraph offices these teleprinters are now the standard instruments. Telegrams from the smaller offices are dictated over the telephone to a phonogram position where a girl sits at a small switchboard into which she can plug her head-set, and with a typewriter on the table before her. As the telegram is dictated to her she types it and at its conclusion takes the message from her machine to put it on to a

A	–	○●●○○○●	P	0	○○●●○●●
B	?	○●○○●●●	Q	1	○●●●○●●
C	:	○○●●●○●	R	4	○○●○●○●
D	WHO ARE YOU	○●○○●○●	S	'	○●○●○○●
E	3	○●○○○○●	T	5	○○○○○●●
F	%	○●○●●○●	U	7	○●●●○○●
G	@	○○●○●●●	V	=	○○●●●●●
H	£	○○○●○●●	W	2	○●●○○●●
I	8	○○●●○○●	X	/	○●○●●●●
J	BELL	○●●○●○●	Y	6	○●○●○●●
K	(	○●●●●○●	Z	+	○●○○○●●
L	)	○○●○○●●		CARRIAGE RETURN.	○○○○●○●
M	.	○○○●●●●		FIGURES	○●●○●●●
N	,	○○○●●○●		LETTERS	○●●●●●●
O	9	○○○○●●●		LINE FEED	○○●○○○●

SPACE ○○○●○○●

KEY:- ● MARKING SIGNAL

○ SPACING SIGNAL.

EACH LETTER TAKES THE SAME TIME TO TRANSMIT BY THE TELEPRINTER CODE

Fig. 8. The teleprinter code consists of a series of five impulses, of two kinds, marking or spacing, for each letter. In each case the letter is preceded by one spacing and ended by one marking impulse.

moving conveyer band which takes it to the teleprinter positions. The operator deals in a similar manner with telegrams dictated by private telephone users or from public telephone kiosks.

At the delivery office a messenger boy is sent out every few minutes to deliver telegrams in a particular area. Away from the crowded centre of the city he will use a bicycle, while for longer journeys he may be mounted on a motor-cycle. When the address of the telegram is a telephone number it is delivered by telephone, a confirmatory copy of the telegram being delivered by the postman on his next round. The post office makes special arrangements to set up telegraph circuits at temporary offices for such events as race meetings. For smaller social events a post office on wheels has been developed. This can be driven straight on to the site of an agricultural show, sports meeting or the like, and connected by cable to telephone lines.

A BUS IN THE MAKING
Finished bodywork is fitted to chassis in the Chiswick depot of the London, Passenger Transport Board.

HOW BUS TRANSPORT IS ORGANIZED

Types of bus service. Planning new routes. Traffic analysis. The survey van and its instruments. Rolling stock and how it is chosen. Allocation by garage. The training school. Overhauls. The duty roster. Ticket punch and way-bill. The run-in to the garage. Cleaning and washing.

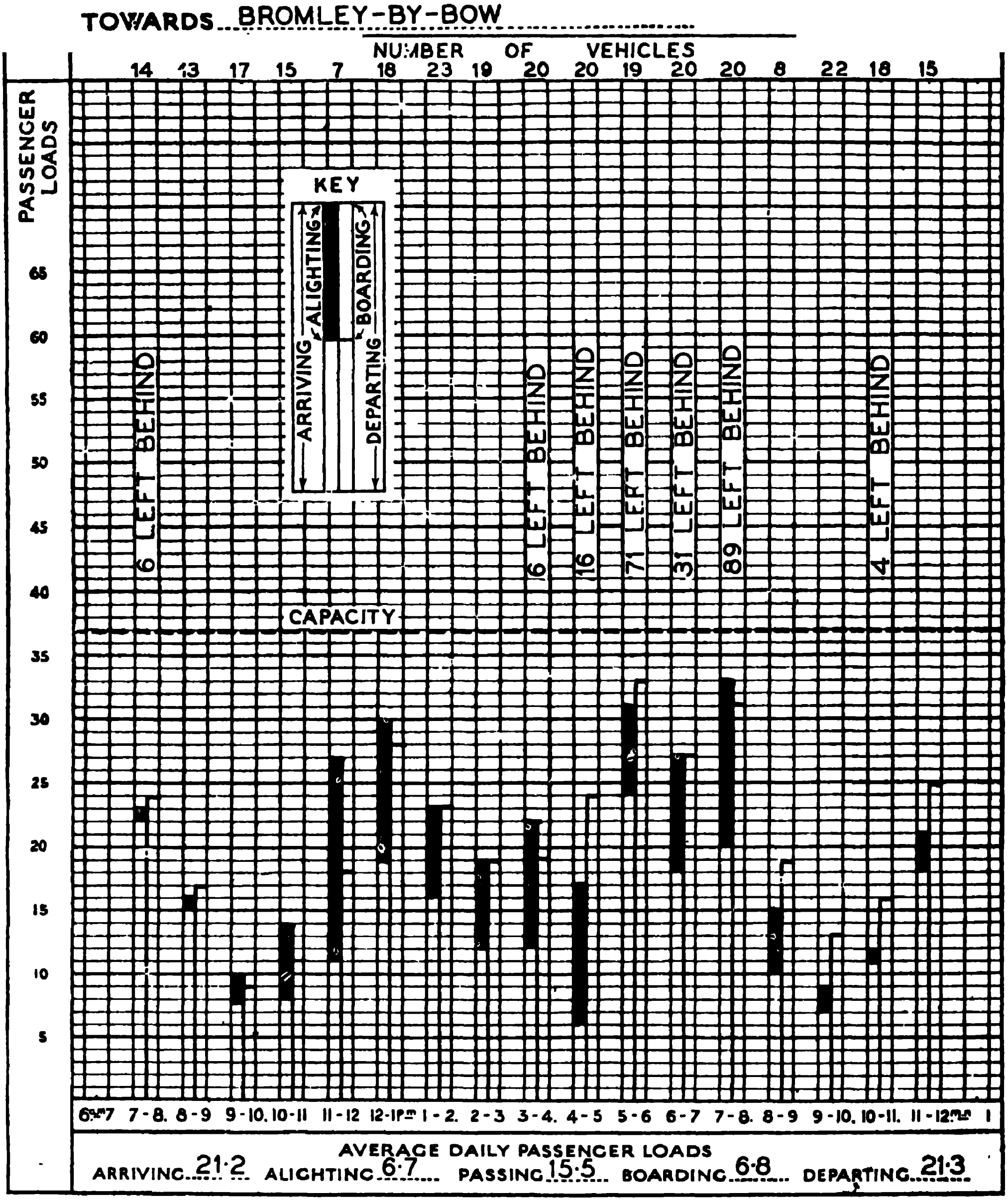
A VAST amount of organization is needed to provide our bus services. There are some 45,000 buses and coaches in the country—the Government calls them public service vehicles in the Acts of Parliament and Ministry of Transport Regulations governing them—and their ownership is divided among many operators. There are a number of large companies, ninety-one municipalities, the London Passenger Transport Board and several thousand small proprietors. The large companies have fleets of from 100 to 1,400 vehicles. The area agreement companies do not compete with one another, but co-operate as far as possible in providing public service throughout their allotted territory, even if it means running perhaps two-thirds of their country routes at a loss. Coaches—express carriages to the law—are run by these companies not only on seaside and other excursions, holiday cruises and private hire, but normally on many daily routes, in which the companies have mutual working arrangements.

The municipal operators vary widely—the Bedwas and Machen Urban District Council possesses three buses housed in the local fire station, and at the other end of the scale comes Birmingham Corporation with a fleet of over 1,000. Some of the municipal undertakings are agglomerations of the transport systems of several towns run to mutual advantage: Burnley, Colne and Nelson in Lancashire have a joint committee of this sort. There are also cases where municipalities and companies run in double harness, as at York, where the West Yorkshire Road Car Company and the Corporation are associated, or Halifax, Huddersfield, Sheffield and Todmorden, where the railways and the municipal authorities have joint bus companies. The London Passenge Transport Board is unique, both in its monopoly powers over nearly 2,000 square miles of London and the Home Counties, and in the magnitude of its operations, which require roundly 6,000 buses and coaches.

It is hard for most of us to detect the growth of our town or city and of its passenger traffic. Sometimes a whole municipal estate is erected, houses becoming occupied in scores inside a few months. More usually houses are built by ones or twos, or in little colonies of forty or fifty. Only the bus operators will realize, by the growth of traffic, just how fast the development is going. In the case of the London Passenger Transport Board all the growth is recorded by the development superintendent's staff on a special map. His experts estimate when a new district is sufficiently developed to need a new bus service. Sometimes routes are planned

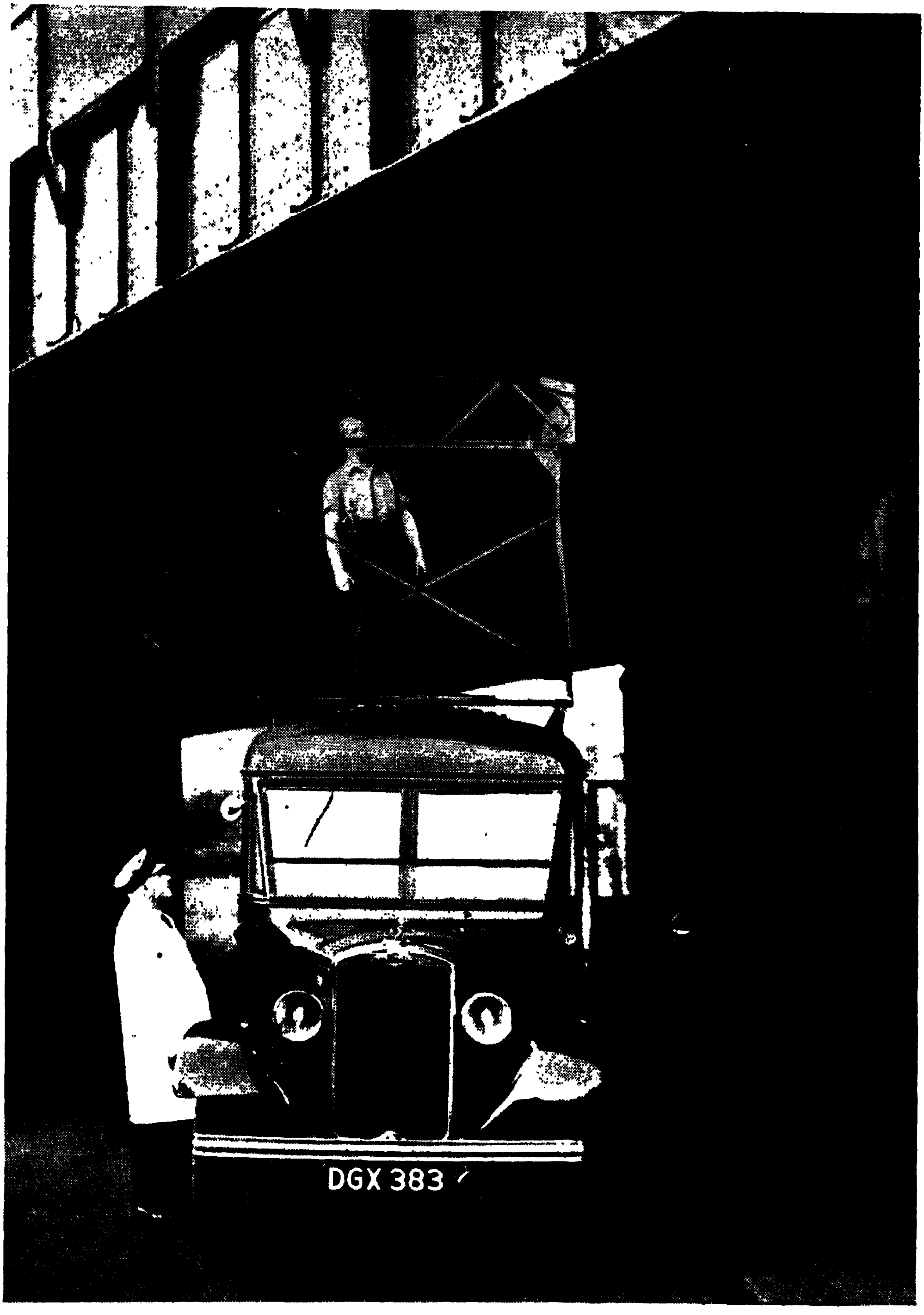
and surveyed far in advance of actual development; they may even be commenced in order to foster it.

There are sixty outdoor men to cover the whole London Transport area assessing new route possibilities, judging probable traffic from long experience, and checking traffic on existing routes. Checking traffic at important loading points along the route is done by spots, or road inspectors, who check the numbers of persons entering and leaving the



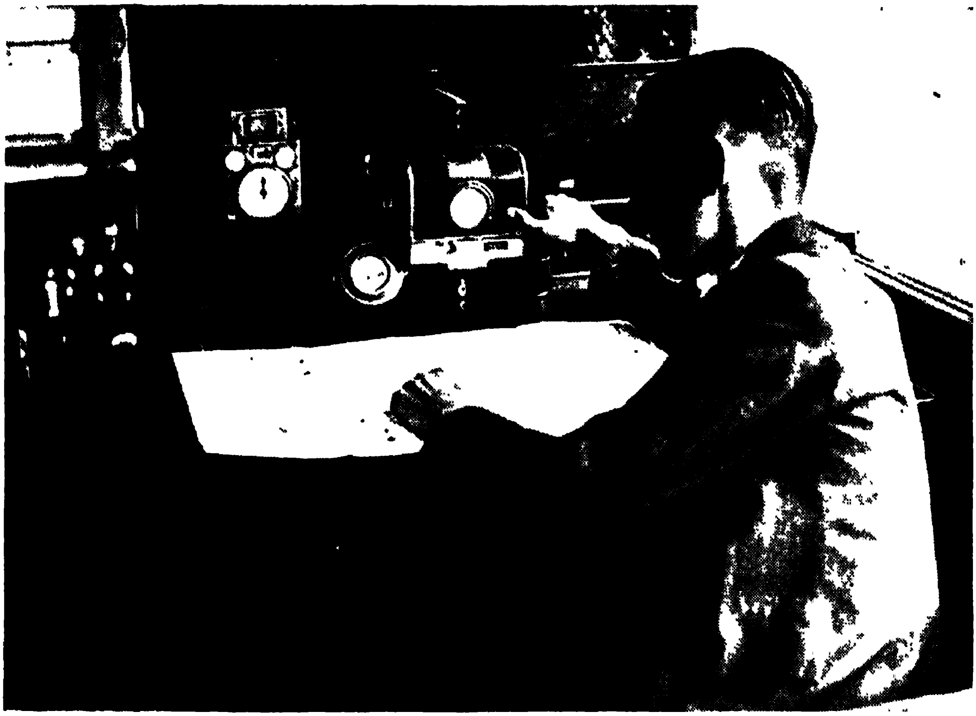
HOW A LOADING CHART IS COMPILED

Fig. 1. Checking traffic at important points along the route is done by road inspectors who note the number of persons entering and leaving the bus, also those left behind. The number of vehicles is noted across the top of the chart. Need for increased service was indicated by the above diagram.



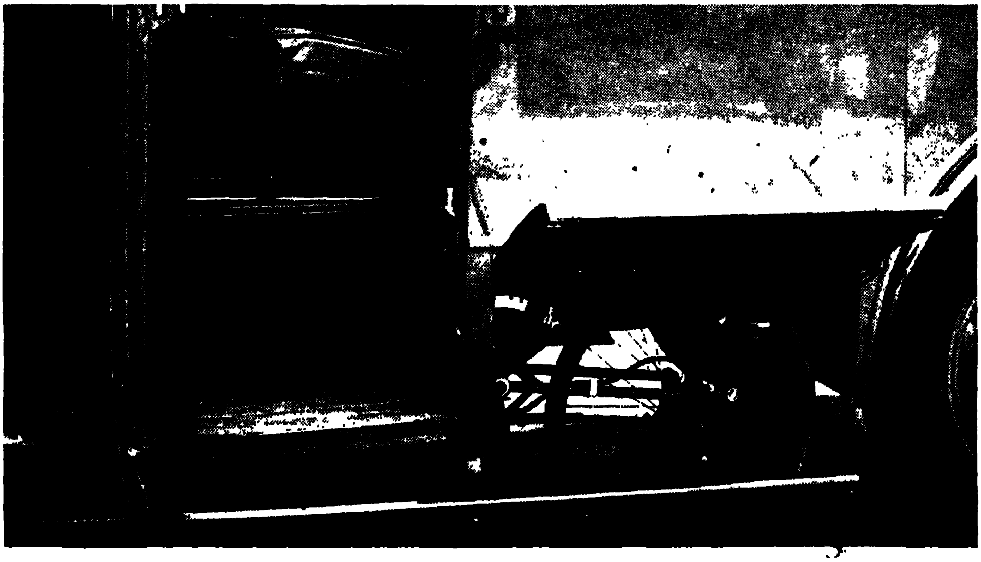
HOW HEIGHTS ARE GAUGED ON A BUS ROUTE

A height gauge shaped like a bus top is fixed above the survey van which is used to mark out the physical features of a bus route. The measurements will decide the type of bus to be used. Various positions are tested under every bridge to ascertain the lowest point of contact.



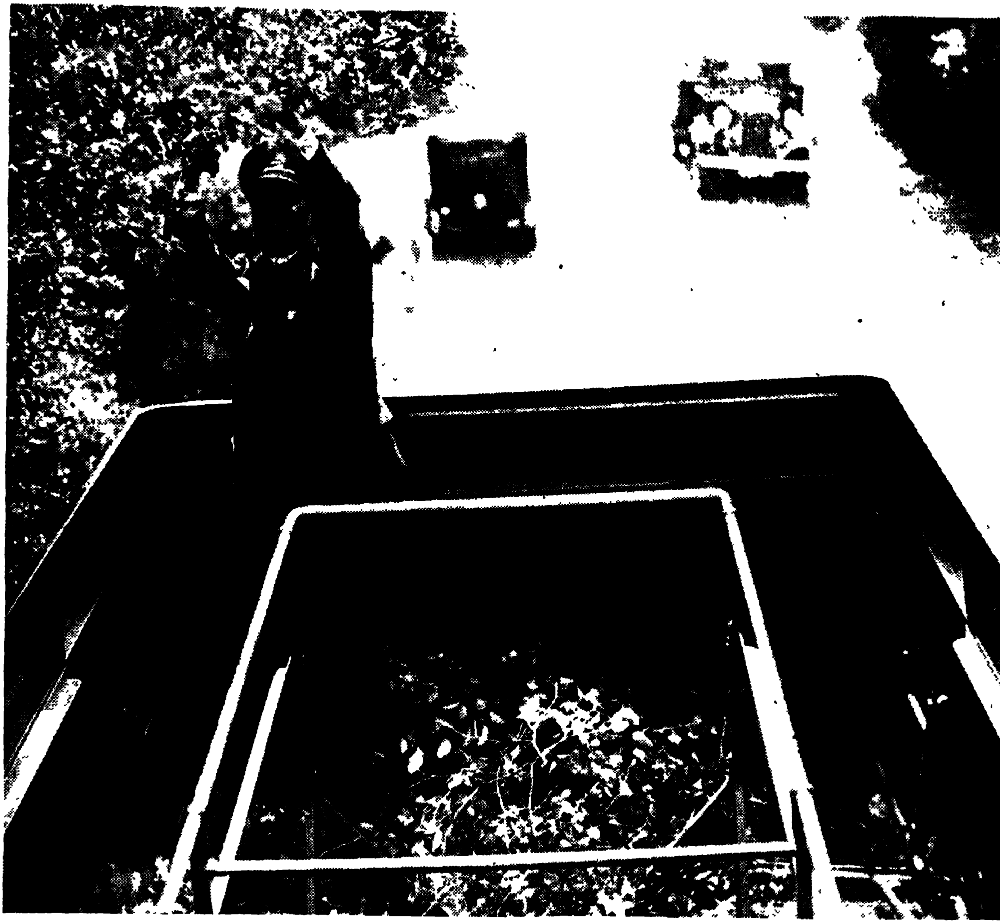
AT WORK INSIDE A SURVEY VAN

Fig. 2. The survey van used by the operating engineering departments of a bus undertaking is equipped with instruments for measuring the gradients and camber of roads, heights of bridges, mileage, etc., thus compiling a record of the physical features of a route.



MEASURING WHEEL WHICH RECORDS THE MILEAGE OF A ROUTE

Fig. 3. One of the most vital measurements made by a survey party is, of course, the mileage of a route. This has an obvious bearing on the construction of the time-table and fare-table. A measuring wheel, as illustrated here, is fixed beneath the survey van and gives the distance from one end to the other. This is taken in both directions, so allowing for variations of the traffic stream.



THE PRUNING BUS ON ITS ROUNDS

Buses which carry no passengers and have no seats are in normal times constantly on the road. These are the pruning buses, whose crew consist of driver and inspector. They travel wooded outskirts and leafy avenues removing the overhanging branches or bushes sweeping the bus.

vehicles on that service and note the numbers, if any, left behind. Great care is taken to obtain useful and accurate information. The weather is recorded for three periods of the day: 7 a.m. to 1 p.m., 1 p.m. to 6 p.m. and 6 p.m. to midnight, with the temperature, rainfall and hours of sunshine. The diagram reproduced (Fig. 1) was taken at Old Ford for buses on service No. 208 between Clapton and Bromley-by-Bow. The number of vehicles in each hour is noted across the top of the chart, and the estimated average number of passengers loaded, and the numbers alighting and boarding are also indicated. Between 7 and 8 p.m. on buses going towards Bromley there were eighty-nine prospective passengers left behind. This, however, does not even represent half a bus load, since the passengers were spread over twenty buses. Any need for additional, or retimed vehicles is clearly indicated, and in fact this service was considerably increased as a result of the investigation made in this instance.

THE TRAFFIC ANALYSIS CHART

The next stage is the preparation of a traffic analysis chart. This shows the passengers carried during the day between each stage, the number of

passengers carried at each rate of fare, and the receipts taken, passengers carried, and number of miles the buses on the service run, with the numbers of trips between the various termini. From this information an increased service can be planned. A new route or an extension of an existing route is first considered purely from the traffic viewpoint, the traffic superintendent's committee agreeing the approximate route and particulars from which a proposal form and a small map is prepared. Probably a check of pedestrians will have been taken on the proposed route from time to time to ascertain what sort of headway might be required. A survey is next undertaken by members of the operating and engineering departments. A van full of the necessary gadgets for ascertaining the physical features of the route is used (Fig. 2).

THE SURVEY VAN

The survey van instruments make the work performed by its staff rapid and accurate. To obtain the gradients of a route, or, equally important, to detect any section on which the camber of the road is so steep as to bring the top of a bus across the kerb or into contact with shop blinds, trees, or other obstructions, there is a gradient and camber gauge. This is a 6-ft. length of aluminium angle fitted at one end with a brass sliding leg, scaled on one side for gradients from 1 in 6 to 1 in 40, and on the other for camber in inches. An ordinary spirit level is clipped on, and the gradient is read off direct. As a bus track is 6 ft. wide, measuring the number of inches drop in 6 ft. gives the extent of the camber of a road, so that the angle at which the bus tilts and the amount by which the top of a double-decker will overhang the curb is given without any complicated calculations.

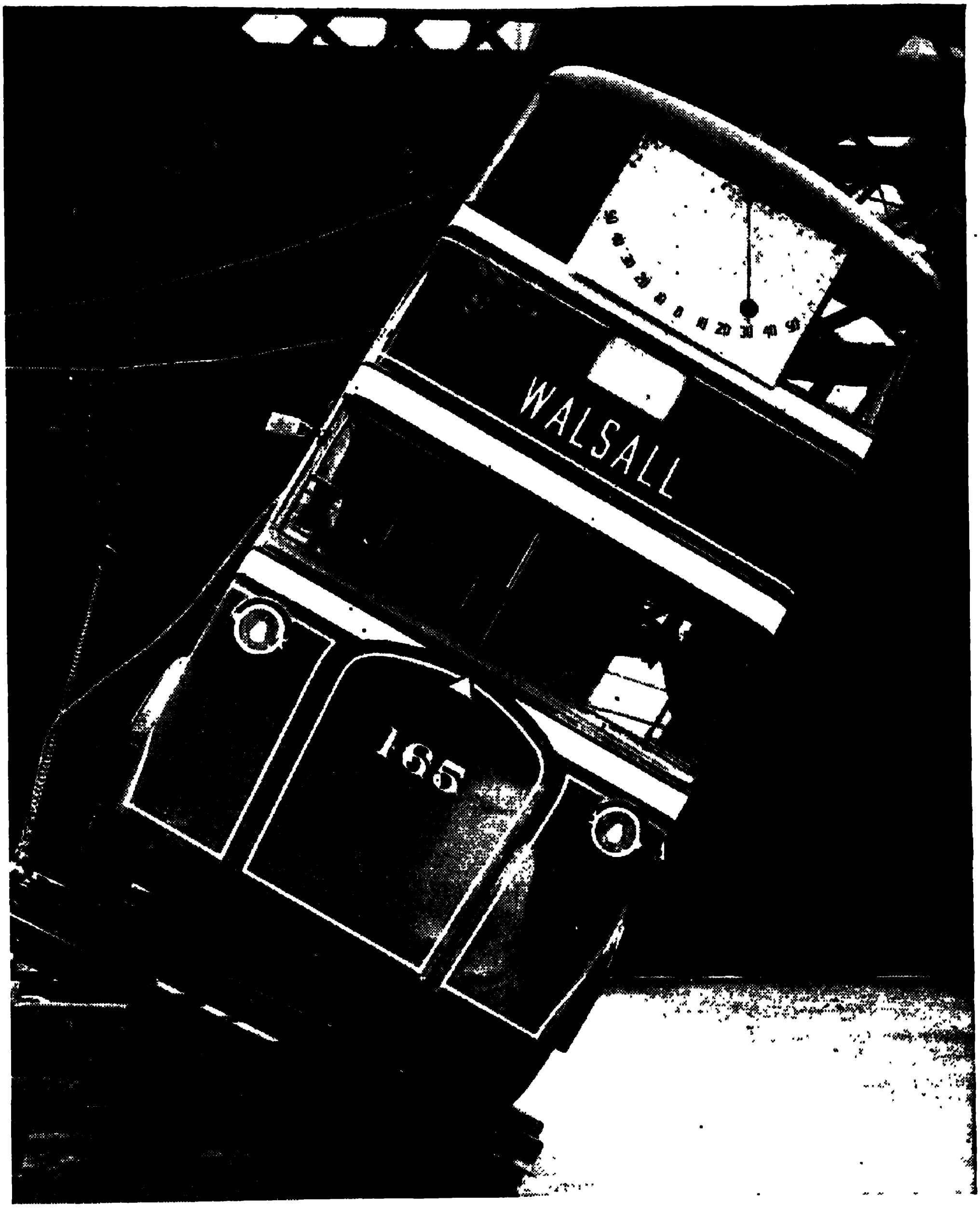
Among the most important fittings is a telescopic brass tube to measure the heights of railway or other bridges over the proposed route. It is graduated in feet and inches for direct readings, and various positions are tested under each bridge to obtain the lowest point of contact. Double-deck buses are of two kinds, the normal high-bridge sort where there are centre gangways on each deck and at least 5 ft. 10 in. between the decks and the low-bridge bus for routes with low railway bridges or overhanging trees where the upper-deck gangway is at a low level over the seats on the offside of the lower deck. As an additional precaution the London Transport survey van has a height gauge with a section across the top reproducing the outline of a covered top bus for testing bridges, trees, tramway and lighting standards and other possible obstacles.

Perhaps the most vital measurement is the mileage of the route. It has an obvious bearing on the construction of the time-table and the fare-table; it also affects the running cost of a particular service and determines the occasions when the buses operating the route undergo overhauls. A measuring wheel gives the distance from one end to the other, and this is taken in both directions (Fig. 3). The reason for this is that traffic islands, one-way streets, and curves on wide roads make practically every London route substantially different according to the direction of travel.

WORK OF A SURVEY PARTY

A further refinement is the record on a chart of the exact time throughout a test journey and the stops made by the car, with the exact speed in all its variations.

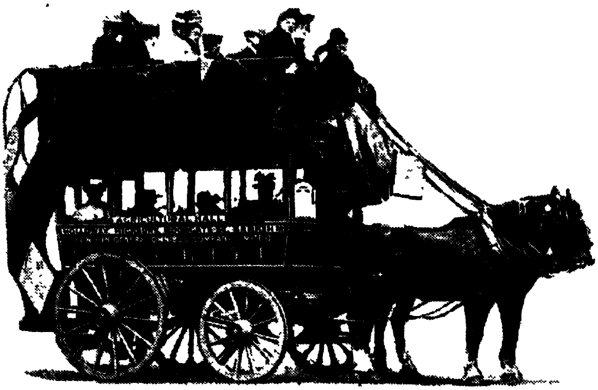
A bus station with covered platforms, waiting rooms and all the amenities of a large railway station is now a commonplace in towns all over Great Britain. Along the route, shelters may be erected in conjunction with the local authority or other operators. The sites for



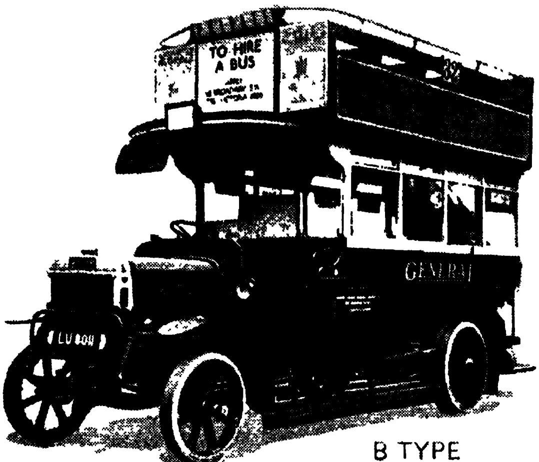
HOW THE STABILITY OF A BUS IS TESTED

Correct balance is of great importance and official regulations provide that all buses should undergo a tilting test of this kind. A six-wheel double-deck electric trolley bus is under trial.

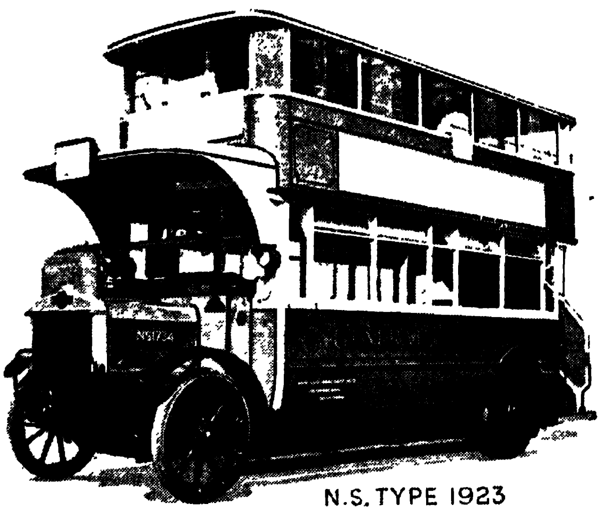
intermediate stopping places, time-table boards, traffic centres for fare stages and suitable places to erect time clocks—where the conductor records the time of passing on a special schedule card—will also be noted by the survey party, with a view to opening negotiations at the proper time with the owners of suitable premises. A report is then made of the results of the survey, a summary being prepared for the undertaking's traffic committee, and they must decide whether



HORSE BUS-GARDEN SEAT TYPE 1900



B TYPE 1910



N.S. TYPE 1923

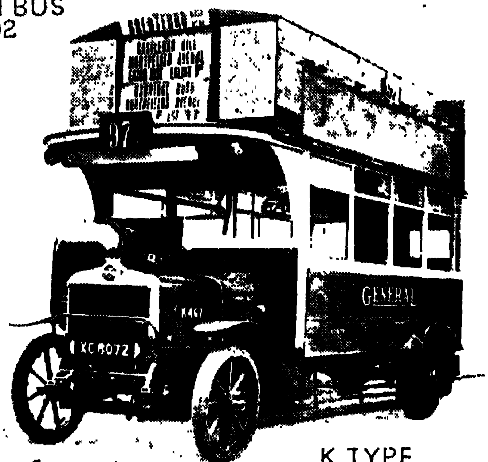
L.S.T. SIX WHEELED BUS 1927

EVOLUTION IN THE DESIGN OF

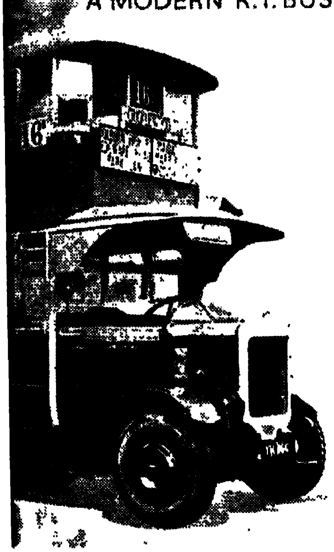
FIRST L.G.O.C.
MECHANICAL BUS 1904

THORNYCROFT
STEAM BUS
1902

A MODERN R.T. BUS



K TYPE
1919

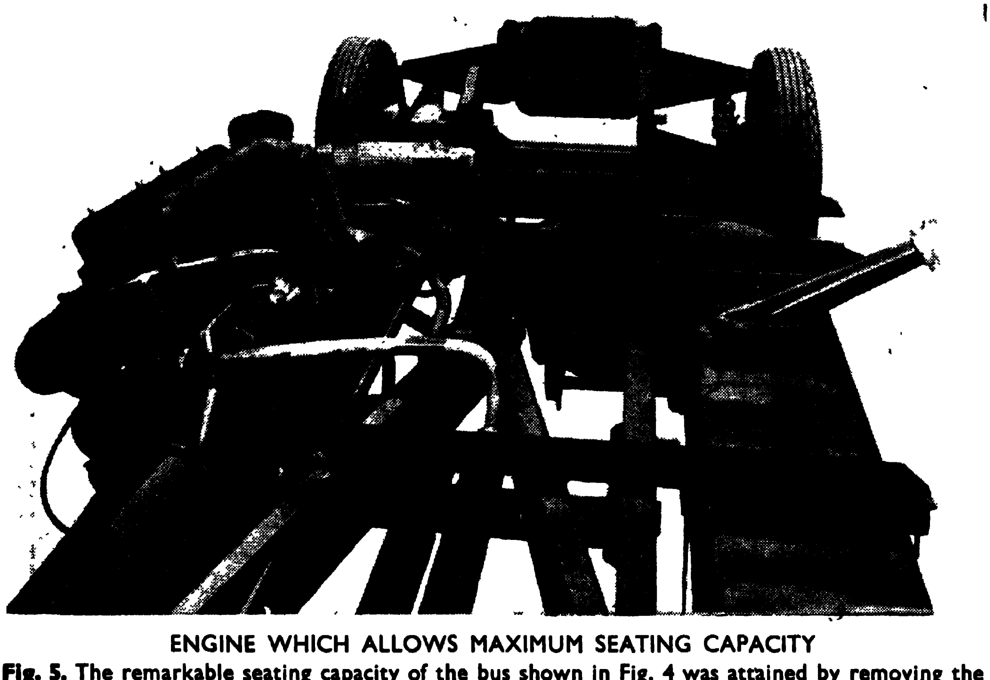


L.T. GENERAL BUS
1931 TYPE

LONDON'S BUSES FROM 1900 ONWARDS

SINGLE-DECK BUS FOR LOW RAILWAY BRIDGE ROUTES

Fig. 4. If possible the double-deck bus is used in a busy district as running costs per mile are hardly more than for a large single-deck vehicle. If traffic is light, however, a single-decker may be used, and in some cases may be inevitable because of the nature of the route. In County Durham, the Northern General Transport Company uses, for a low railway bridge route, the design shown above, evolved in its own workshops, seating forty passengers. It has a front entrance, the advantage of this being that the driver can see what is happening on the front step. This arrangement makes for safety and also effects a saving in time at stops.



ENGINE WHICH ALLOWS MAXIMUM SEATING CAPACITY

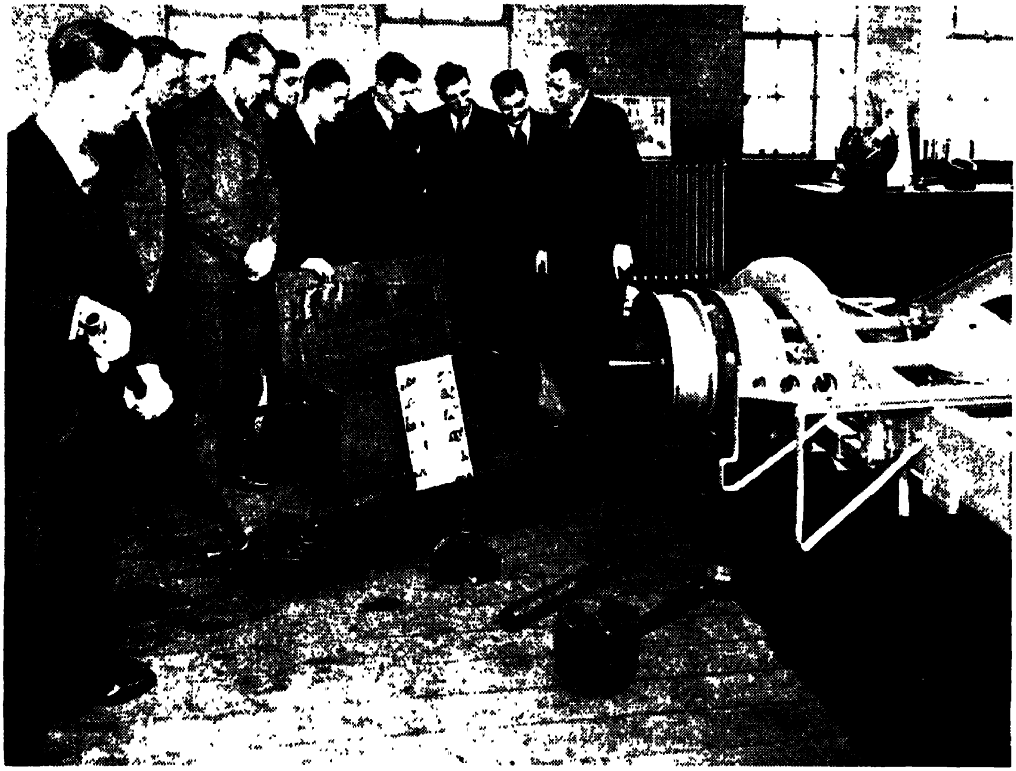
Fig. 5. The remarkable seating capacity of the bus shown in Fig. 4 was attained by removing the engine from the conventional position in front and placing it at the side of the chassis. The tilted side arrangement of the Diesel engine is seen in the above illustration. It is, of course, of low height so that it fits comfortably under the seating space allowing the maximum amount of room.

application should be made to the Traffic Commissioners for a licence. The Traffic Commissioner and, in London, the police go over the route with the sort of bus it is proposed to run, and draw attention to difficulties encountered, or restrictions which must be applied in the interest of safety. A point-to-point time-card with the times of each individual duty is supplied to each driver to aid him in keeping time on the route; he naturally consults this, and so, if an obstruction which can be negotiated by exercising a certain amount of care cannot be removed, a red overprint is placed on the card to be a constant reminder. When the service is approved the rolling stock must be selected well before the date of operation. If the route runs through a busy district and it is at all possible, the economical double-deck vehicle will be used. It costs hardly more to work one of these a mile than to run a large single-deck bus. If traffic is light a single-deck or even a one-man single-decker with fewer than twenty seats is required.

How the modern bus has developed since the beginning of the century is shown pictorially on pages 214-215. In London the largest class in the fleet is the STL type Diesel-engined double-decker, seating normally fifty-six passengers. A refined model, known as the RT, incorporating air-operated gearbox, and illustrated here, is in process of development. Some of the early STL type seated sixty passengers, but four seats had to be given up to accommodate the extra weight inside the limits allowed by the Ministry of Transport, of the Diesel oil engine. This is cheaper to run, but instead of the gas being ignited by an electric spark as in the petrol engine, the head of compressed air at high pressure ignites a fine spray of oil. Pressures are much higher and stresses are greater, so that heavier construction is needed.

SPECIALLY PICKED DRIVERS ARE NEEDED TO NEGOTIATE THIS TURN

Fig. 6. On the Bargoed route served by the West Monmouthshire Omnibus Board comes this right-angle bend—one of two—leading under a low, narrow railway bridge, where the wheels must be turned at a precise spot. Special skill in driving and frequent overhaul of vehicles are required.



DRIVERS LEARN TO USE LIFTING GEAR AT LONDON TRANSPORT'S TRAINING SCHOOL

Fig. 7. A high standard is required of the bus driver and the London Passenger Transport Board has a complete training school at Chiswick which grew from the first central school established in 1914. At one time men were taught to drive, but at the present day, under normal conditions, candidates must be already competent drivers and come between certain limits of age and height. Men are given up to thirty days intensive training in which to satisfy the Board's requirements.

Besides the high-bridge and low-bridge double-deck bodies mentioned there are other differences. The six-wheeled bus, at one time so popular, is not now greatly favoured for double-deck work, as tyre wear on curves and maintenance is increased, but Leicester has some fine sixty-four-seaters replacing trams. For electric trolley buses, which enjoy weight concessions over motor buses, however, the six-wheeler is still built and can accommodate seventy seats. Incidentally, the trolley bus is regarded as a convenient substitute for electric trams, especially where the tramway owns its own power station and is cheaper to operate than the Diesel bus on dense traffic routes.

Front entrance double-deck buses are popular among certain operators on long distance coach routes. The driver can see what is happening on the front step, making for safety of the passengers and a saving in time at stops.

WHERE SPECIAL DESIGN IS NEEDED

For single-deck buses the six-wheeler is still popular where traffic is heavy—on low railway bridge routes in County Durham, the Northern General Transport Company uses a special design, evolved in its own workshops, seating forty-four passengers; there is a corresponding front entrance forty-seat four-wheeler (Fig. 4). These remarkable capacities are achieved by removing the engine from the conventional position in front and placing it at the side of the

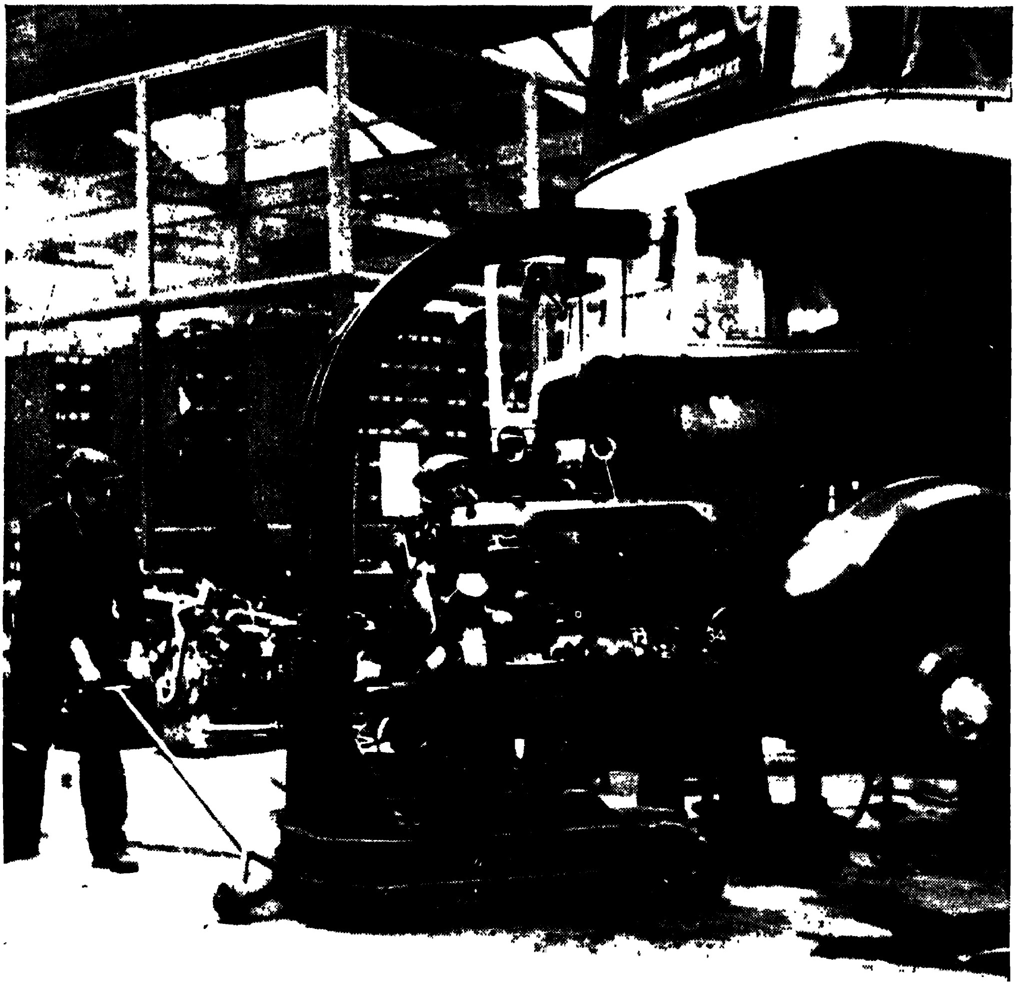
chassis (Fig. 5). An engine of low height is employed to fit under transverse seats.

Special circumstances call for heroic measures. In South Wales and Monmouthshire much of the value of the bus lies in making connexions over the mountains from one steep-sided narrow valley to the next, instead of going up and down the valleys as do the railway routes. Served by the West Monmouthshire Omnibus Board, Aberbargoed Hill, down into Bargoed, is a steep pitch, falling at 1 ft. in $4\frac{1}{4}$ ft. over a loose surface, and ending up with two right-angled bends, the second of which leads under a low and narrow railway bridge, little better than a cattle creep in dimensions (Fig. 6). For safety reasons and to avoid wear on the brake linings the buses descend in low gear, using the fast revving engine as an air compressor. As a result of all the low-gear work the engines require heavy overhaul every 10,000 miles, whereas vehicles on normal routes run perhaps ten times that distance. Tyre wear is also on a terrific scale owing to the loose stones. Eight specially picked drivers are employed and great skill is called for on their part in judging the turn under the bridge. It is a testimony to the drivers' care that no accident has marred the use of the route.

The buses having been chosen, they are allocated to a suitable garage or garages for operating the service. One can learn the garage in a great many instances because the buses are labelled to enable the engineers to recognize them. Birmingham and Midland buses—the largest fleet outside London—carry heraldic devices, coloured quarterings, crosses, shields and circles. Other companies use geometric devices or plain letters. The London Passenger Transport Board uses combinations of letters to indicate its garages—such as BK for Barking, U for Upton Park, DG for Dunton Green, etc. These are shown on

HOW THE SKID TEST IS CARRIED OUT

At the Chiswick training school the conditions which the bus driver will have to cope with are faithfully rendered; in fact a miniature road system, complete with signals, is laid out. The skid test illustrated in the above photograph is one of the important items of the training programme.



REMOVING AN ENGINE FOR OVERHAUL

Fig. 8. Buses usually receive a complete annual overhaul at a central works, this taking two days.

little aluminium stencils on the front of each side panel. Alongside, a stencil shows the running number—the number of that day's turn of work in the time-table—so that any road inspector can at once recognize the vehicle, know its garage and check its time.

Organized staff training at a central school was begun in 1914 by the London General Omnibus Company, and was transferred to the premises at Chiswick works eleven years later (Fig. 7). Whereas in the early days men were trained to drive, a later rule is that candidates must be already competent drivers between the ages of twenty-six and thirty-five, not under 5 ft. 7 in. or over 5 ft. 11 in. in height. They are given up to thirty days of intensive training in which to satisfy the Board.

The running of a bus route is a no less complicated process than its original planning. At one time bus fleets generally comprised many different makes and the necessary annual overhauls were made in local garages, taking perhaps a fortnight. The overhaul of London buses now occupies only two days. Special care is given to steering gear.

When the time schedules of the buses

have been prepared, duty schedules are made out, and by a roster system the crews change from early to late duties in rotation, care being taken to see that they have the necessary number of hours of rest between successive late and early turns. The men can consult the rosters to ascertain for some time ahead what turns they will be working, and thus decide how they can spend their leisure. Meal reliefs are usually achieved by bringing out sufficient extra crews to enable the men to drop down from bus to bus so that at a terminal point where there are catering facilities or a staff canteen the original staff can take their meal relief before resuming duty. Spreadovers enable a crew to work a bus in the morning rush hour for a few hours, and to return to work later in the day to assist in the evening peak.

To the management of a bus undertaking one of the best sources of information as to how a service is faring is the conductor's way-bill. With the ticket punch, of course, it provides also a check upon the amount of cash taken (Fig. 9). There is a popular fallacy that the confetti made by the punchings is always counted and classified according to the ticket colours to indicate the receipts which should have been taken. Actually, this is only done when there is a discrepancy between the way-bill and

CHECKING TICKET CLIPPINGS AGAINST THE NUMBER SHOWN ON THE WAY-BILL

Fig. 9. The illustration shows a standard bell punch used by the bus conductor when issuing tickets, and the process of checking the number of clippings against the number of tickets recorded on the way-bill as sold. The number of clippings is counted, however, only when there is a discrepancy between the way-bill and the number registered as punched. The way-bill is made up by the conductor at the end of a shift and handed in at the garage with the box of tickets and cash.

WASHING A BUS AT THE END OF A DAY'S WORK

Water is pumped to a high pressure in the garage and sprayed over the bus after the windows have been shut. The work of cleaning is completed with long brooms. Periodically vehicles are thoroughly washed down inside, seats vacuum cleaned, and the interiors sprayed with disinfectant.

the number of tickets registered as punched. At the end of the shift the conductor makes up his (or her) way-bill and hands back the box of tickets with the cash at the garage office. Discrepancies between cash and way-bill are posted on a shorts and overs list.

You may have wondered how the stock of tickets is kept. In London most of the central area bus conductors receive their tickets in neat little boxes, filled at a central depot. There are two boxes for each turn, which is known by number and route. These are sent to and from the garages by van nightly.

To lessen the conductor's work many machines are in use. Those that print all of the tickets are very suitable on simple routes without complicated issues, such as transfers and return tickets. Another type prints certain information on a preprinted form. Still a third method is for the conductor to write in pencil particulars on a partly printed form, a carbon copy being retained in a locked compartment inside the machine for analysis at the company's office.

At the end of the day's work the run-in to the garage is the preliminary to a thorough overhauling and cleaning. The bus is swept out and the seats also are vacuum cleaned. Periodically the vehicles are very thoroughly washed down by means of hose pipes.

Water is pumped to a high pressure in the garage and sprayed over the bus after the windows have been shut. The work of cleaning is completed with long brooms. The bus is then parked ready to run another hundred miles next day.

HOW TRAFFIC LIGHTS WORK

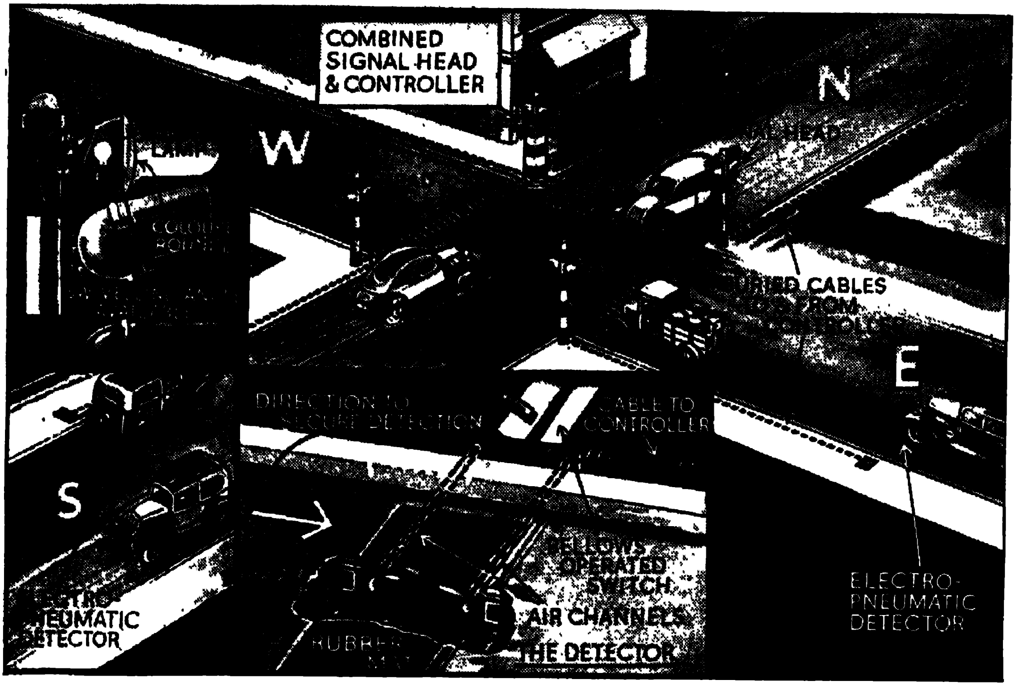
Essential parts of road traffic signals. Switching mechanism. Timing mechanism. The syphon analogy. Changing lights at fixed intervals. Detectors and their operation. Limiting right of way.

MANY types of road traffic signals are now in use. Common to all are, first, the signals or lanterns, by means of which drivers, riders and pedestrians are made aware of what is expected of them, or of what they can expect; second, the switching mechanism, by which the lamps in the signal are controlled; and third, the timing mechanism, which determines when, and in what sequence, the light shall change from one colour to another. The signals themselves are such familiar sights that but little description is necessary. They consist of a housing which carries the actual signal units, each of which comprises a lamp, a reflector, and a coloured glass roundel for giving the colour signal required. A typical signal is shown, and its component parts exposed, in Fig. 1, one of the lamps being swivelled to its available limit.

The switching mechanism, by which the various lamps are switched on or off, is, of course, a very important part of the system, the various contacts which control the lamps having to be so arranged or interlocked that it is not possible to give two conflicting signals simultaneously. There are many ways in which this may be attained, perhaps the simplest being to operate the signals by means of a system of cams rigidly mounted on a shaft, all the cams being thus rotated together. Part of a camshaft with three of its associated cams and contact springs for the control of the lamps is shown in Fig. 2, from which figure it will be seen that cam 3 has operated and opened its associated contacts. Cam 2 is still maintaining its contacts in the closed circuit position, and cam 1 has still to operate its contacts. The sets of springs must always operate in a precise order.

Timing mechanism may also be of many types but that most commonly used is the condenser-gas discharge tube type. This consists of a source of direct current, a condenser, a variable resistance, a neon or other gas discharge valve and a relay. A condenser is a piece of electrical apparatus on which a charge of electricity can be stored, in much the same way that water can be stored in a jar, whilst a variable resistance in an electrical circuit can be likened to a tap filling the jar. As the tap is turned on or off to increase or decrease the rate of flow, so is the rate of electrical flow increased or decreased by withdrawing resistance from or imparting resistance into the circuit.

A gas discharge tube has the peculiar property that it will not pass any current until the electrical pressure voltage across its terminals reaches a specified figure, but once having commenced to pass current it will continue to do so until the pressure drops below a much lower figure than the original striking voltage. Having once ceased to pass



DETAILS OF A TRAFFIC LIGHT SYSTEM

Fig. 1. The diagram shows the housing of signal units comprising lamp, reflector and coloured glass roundel. The time periods of signalling are affected by the passage of the traffic over detectors or mats which function as switches in relay circuits. A limiting device provides for making the neccessary change in the right of way after a certain period of time has elapsed.

current it can only be restarted by again raising the electrical pressure to the required value.

A good analogy with the neon tube as used in the traffic signals timing circuit is that of the syphon tube in a water jar. Water can commence to flow only when its level rises above the bend and the flow ceases as soon as the water falls below the bottom of the short end of the tube.

The relay used in the timing circuit simply consists of a coil of wire wound on a soft iron core, which, when energized, acts as a temporary magnet, and is capable of attracting an armature. The consequent movement of the armature closes one or more contacts, and completes an electric circuit to do other work. A typical condenser-gas discharge tube is shown in Fig. 2, while the same figure shows the analogy with a syphon. If an electric supply is connected to the points marked + and − in A, Fig. 2, current will flow into the condenser at a rate determined by the setting of the variable resistance. As it does so the electrical pressure across the condenser rises in just the same way that the water rises when the tap fills the jar.

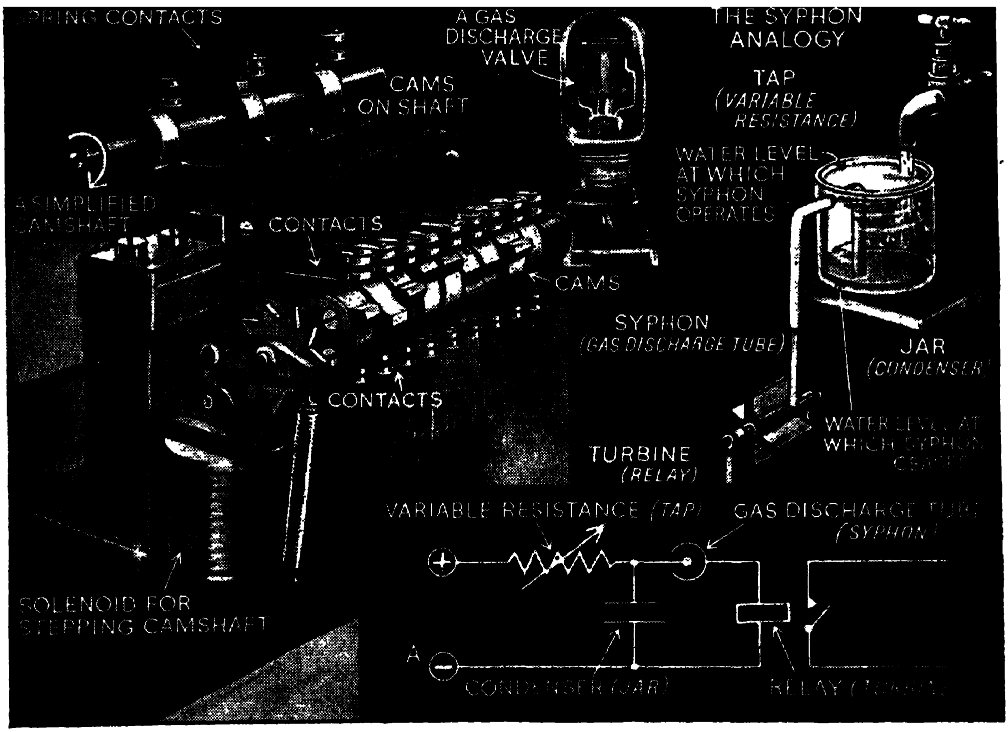
The gas discharge tube and relay in series are connected across the condenser. The electrodes of the discharge tube at first prevent current flowing until eventually the pressure is sufficient to cause the tube to flash and pass current, in the same way as the syphon begins to pass water from the jar because the level has risen to the bend. The relay is actuated just as the turbine would be. Having once begun, the flow of current continues until the voltage on the condenser is reduced to the lower figure at which the tube extinguishes. This is equivalent to the water in the jar falling

to the low level below the end of the short tube. The relay ceases to be actuated—equivalent to the turbine coming to rest—and the control contacts spring apart. With an understanding of the above points it is now possible to build up a composite picture of a complete traffic-signal system.

Before proceeding further, however, we should return for a moment to the camshaft. This may be rotated by various means, but the most useful is to move it step by step by means of an electromagnet coupled to a pawl and acting on a toothed ratchet wheel firmly coupled to the shaft. By operating the shaft in this way each step produces a definite change in the signals and may also modify the timing arrangements.

Fig. 3 shows in diagrammatic form the complete circuit of a simple controller of the type which changes its signals at regular fixed intervals. In this diagram the full camshaft is not shown, only the contacts being indicated, the figures in the contacts showing the camshaft step in which that particular contact is closed.

Now assume the shaft to be in position 1. Contacts D and J will be closed and current will flow through lamps N and S to show red to the north-south route and green to the east-west. The condenser T will charge via contacts A and the timing resistance K and at the end of the period, the tube U will flash and pass current through the relay V. When V operates it closes the circuit to



PRINCIPLE OF THE SWITCHING AND TIMING MECHANISM

Fig. 2. The mechanism by which the lamps are switched on or off include contacts so arranged or interlocked that two conflicting signals cannot be given at the same time. This is attained by a system of cams mounted on a shaft. Of the three cams shown at the top of this illustration it will be seen that cam 3 has operated, opening its contacts. Cam 2 is at closed position, cam 1 has still to operate. Timing is governed by an electrical flow analogous in working to a syphon.

the electro-magnet X, via its springs W, and X steps the shaft to position 2.

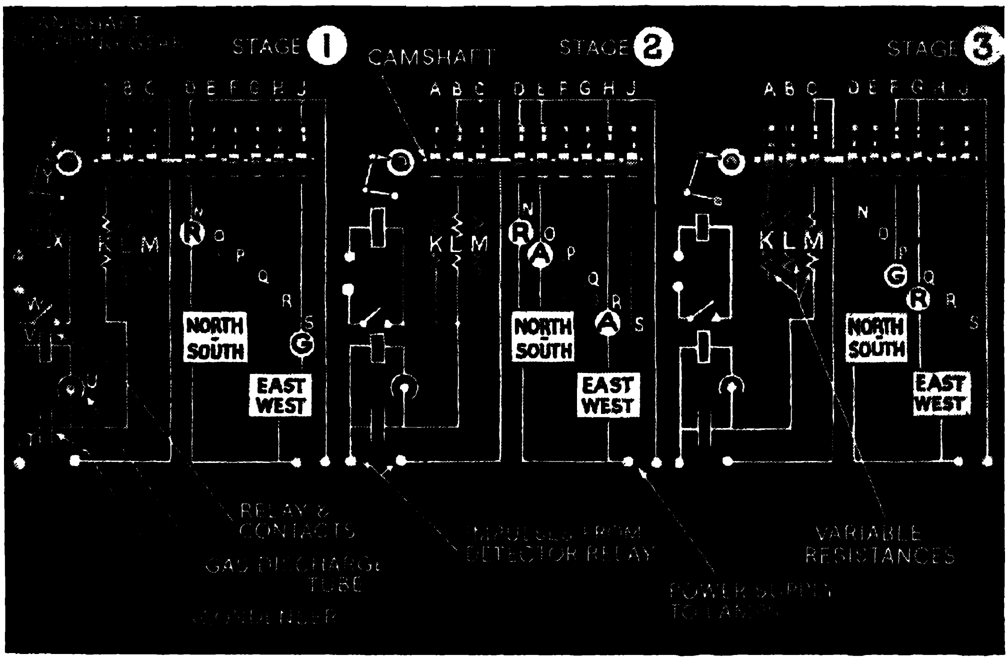
In position 2 the lamp is extinguished by the opening of contact J thus removing the green signal from the east-west route. Lamp N continues to glow to maintain the red signal to the north-south and the east-west routes, the contacts E and H being now closed.

The position now is that the red and amber lamps are glowing on the north-south route whilst the amber alone is showing on the east-west. Contact B is also closed and the condenser now charges *at a different rate* from that of the last step via the timing resistance L.

When the tube again flashes and the shaft steps to position 3, the lamp P glows to show green to the north-south route and lamp Q shows red to the east-west, the new period being timed via resistance M. Similar conditions and circuit changes occur step-by-step until the complete cycle is made.

Of late years controllers of this type of fixed cycle have largely given way to a later and more efficient type in which the time periods are affected by the passage of the traffic over detectors (Fig. 1).

The detectors function simply as switches in the relay circuits. When the relay on the route which has not the right of way is operated, it remains so until the right of way is given to that route. If the right of way already exists the relay operates only while the detector operates. A limiting device provides for change in right of way after a given period.



COMPLETE CIRCUIT OF A SIMPLE CONTROLLER

Fig. 3. The principle demonstrated is that of a system changing the signals at fixed intervals. When the camshaft is in position 1, contacts D and J will be closed and current will flow through lamps N and S to show red to the north-south route and green to the east-west. In position 2 the lamp is extinguished by the opening of contact J thus removing the green signal from the east-west route, while the red and amber lamps glow on the north-south route and the amber alone on the east-west. When the tube again flashes and the shaft steps to position 3 the lamp P glows to show green to the north-south route and lamp Q shows red to the east-west, the new period being timed via resistance M. The sequence is continued step by step through a complete cycle.

WHAT HAPPENS WHEN YOU SOUND A FIRE ALARM

The mechanism of a fire alarm. Recording the alarm call. Communication by telephone. The fire station control room. The electrical connexion of street boxes. Closed loop working. Electrical supervision. Safeguards against failure.

THE typical street fire alarm consists of a metal cased box mounted on a pillar. Inside the box (Fig. 1) is a spring-driven electro-magnetically controlled mechanism, which is brought into operation, for the purpose of transmitting its own particular alarm signal to the fire station, by simply breaking a glass and then pulling the handle. This handle is placed on the front of the box and pulling it releases a catch, operating the small lever indicated. This, in turn, sets into motion a whole chain of events.

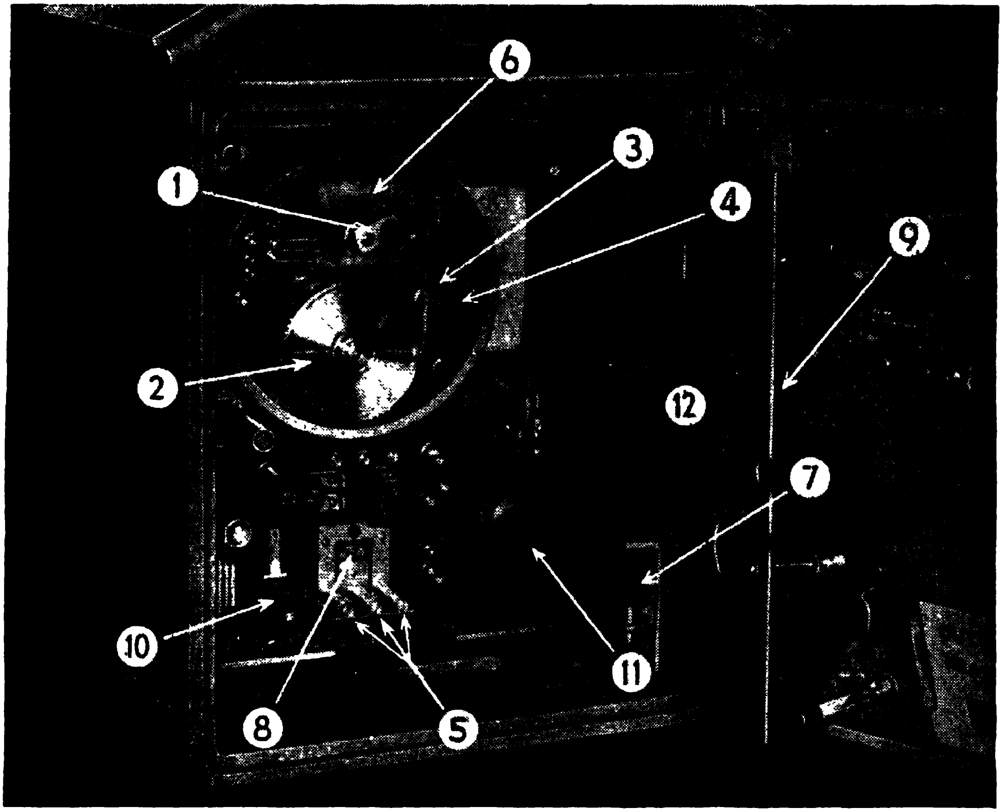
The fire alarm boxes are located at key points in all the principal streets and are electrically connected to the fire station. Each fire alarm box has its own number for identification purposes and the mechanisms inside the boxes, although identical in all other respects, are so modified that each box when operated transmits its own particular number by momentarily breaking the electrical circuit a corresponding number of times. For example, box number 231 would first interrupt the circuit twice, a brief pause would then follow, the circuit would then be interrupted three times, another brief pause and finally one interruption would occur.

At the fire station the number of the box from which an alarm signal is being sent is rapped out on a loud sounding gong, and is also permanently recorded by holes punched in a paper tape, as shown in Fig. 3. Both the date and the time at which any signal is received are also automatically printed alongside the holes punched in the tape. The crew at the fire station thus receive the signal both audibly and in the form of a permanent record. A moment's reference to a board containing the street locations of all the box numbers in large type informs the crew from where the alarm signal was transmitted and they are thus able to go at once to the box concerned.

RECEIPT OF AN ALARM CALL

Whilst the foregoing outlines the essential features of most street fire alarm systems, many other additional features are frequently provided, the complete installation in any particular case depending upon local requirements and circumstances. In the case of very large stations, at which living quarters are provided for the firemen and their families, the receipt of an alarm call automatically rings an alarm bell in the quarters of each man on duty call, opens the fire engine room doors, secures right of way at any adjacent road crossing by changing, if necessary, the street traffic signals and may even operate the self-starters to get the engines ticking over. During night time, the receipt of an alarm call usually switches on the lights in and about the engine room and in the quarters of the men on duty as well.

In the case of fire stations of smaller size, where the men live in houses at shorter or greater distances from the station itself; the receipt of a fire call can



HOW THE MECHANISM OF A STREET BOX WORKS

Fig. 1. The fire alarm street box is electrically connected to the fire station. The act of pulling the lever operates the trip-cam lever (1) and the box then transmits its own number to the station by breaking the electrical circuit a corresponding number of times. The parts here numbered are: (1) Trip-cam lever, operated by pulling handle; (2) code wheel; (3) impulsing lever; (4) pulsing contacts; (5) incoming and outgoing lines; (6) controlling magnet coils; (7) test plug; (8) test panel; (9) telephone for testing; (10) tapper key for code testing; (11) sounder repeating signals; (12) inner door. The function of the essential mechanical and electrical elements is illustrated in further detail in Fig. 3.

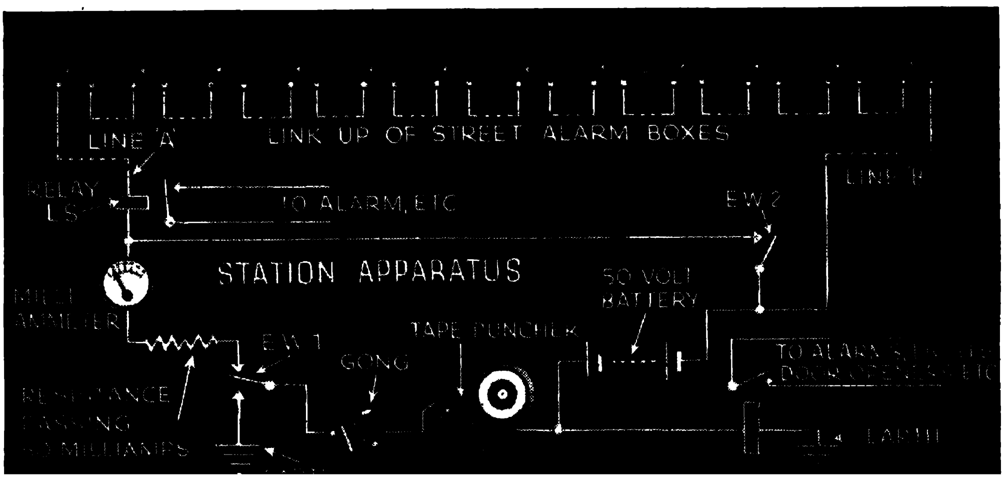
be arranged to actuate a siren on the top of the building to give the general alarm, whilst individual alarms are extended to the houses of the firemen. By simple adaptation the siren can be made to sound out the number of the street box from which the alarm call was transmitted. In some cases a town or district may be served by one or more

main fire stations around each of which is grouped several sub-fire stations. This arrangement has many advantages, chief of which is the saving of time by the fire-fighters in reaching the seats of fires. The fire alarm calls are received audibly and are not only recorded on the punched tape at the sub-station concerned, but are automatically repeated to the main fire station as well. The chief officers at the main station are thus informed of all fire calls and, whilst immediate fire fighting action is taken by the sub-station crew, the main station is enabled to keep in touch with developments by telephone so as to dispatch additional machines if the emergency should require them.

Telephone communication is essential not merely between the seat of a fire and the sub-fire station, but right through to the main fire station also. In some forms of street box access to the telephone is by the firemen only, by opening the doors of the street box. Some towns use a combined form of street box, the fire alarm being on one side and an ambulance telephone on the other. With this type of box, fire alarms are given by first breaking the glass and then giving the handle a quarter turn, whereupon the mechanism is set in motion to transmit the box number to the fire station and the box door swings open to give access to the hand micro-telephone. When this is lifted to speak, the caller is put into communication with the officer at the fire station. When the glass is broken on the ambulance side, the door swings open at once and the ambulance signal is automatically given at the fire station or ambulance station, although in this case without the box number being transmitted to the fire station.

STATION CONTROL ROOM

Fig. 4 shows a fire station control room. The tape punch machines and the date and time stamping apparatus will be seen accommodated in the cabinets on the left-hand side. It has also a switchboard, at the top of which is a luminous indicator automatically displaying various fault conditions in the event of



ELECTRICAL CONNEXION OF STREET BOXES IN SERIES

Fig. 2. The street boxes are connected electrically in series, each circuit being termed a loop and containing from ten to fifteen boxes. When at rest each box is short-circuited by a pair of contacts, but when in motion and in process of transmitting a call the short-circuiting contacts are open and the earthing contacts are closed. The pulsing contacts open and close according to the number of the box concerned. Electrically, the system is under continuous and perfect supervision

disconnexions in loop circuits, blown fuses, failure of electricity mains and so on. The panel on the right-hand side of the switchboard contains the firemen's call bell keys and miscellaneous apparatus. A two-way key switch is provided for each fireman and the key switches are set according to the particular men on duty, who are thus automatically called in the event of an alarm.

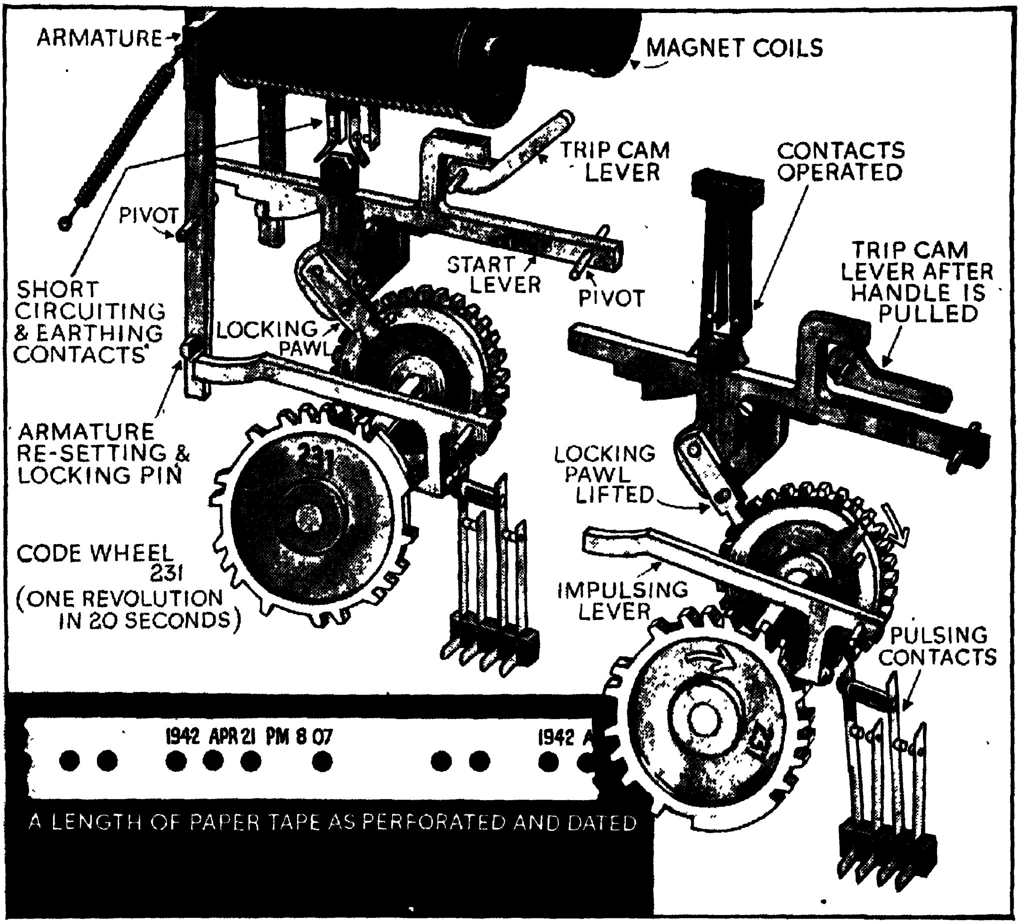
In some stations a luminous box number and street name indicator is affixed to the wall of the engine room near the fire engines. When a fire alarm call is received, this indicator automatically displays both the number of the box from which the alarm was given and the street in which it is located.

CONNEXION OF STREET BOXES

The street boxes are connected electrically in series, each circuit being termed a loop and containing from ten to fifteen boxes. The line wires employed are usually in the same cables as the public telephone service, from which, however, they are electrically isolated. Fig. 2 gives a skeleton diagram showing the principal electrical connexions of the street boxes. When at rest, each box is short-circuited by a pair of contacts, but, when in motion in the process of transmitting a call to the fire station, the short-circuiting contacts are open and the earthing contacts are closed. During operation, therefore, the three coils and the impulsing contacts are brought into circuit. The manner in which the coils function will be described later. The pulsing contacts open and close according to the number of the box concerned. Referring now to the loop circuit (Fig. 2) it will be seen that normally a current of fifty milliamperes flows through the short circuiting contacts of all the boxes and round the whole circuit, which under normal conditions remains closed, and therefore maintains relay LS in steady operation. This is known as closed loop working. If any abnormal condition arises, such as a break in the line wires or a failure of the battery, etc., relay LS releases its contacts to give a warning signal and causes relay contacts EW1 and EW2 to change over and thus rearrange the loop circuit for earth working.

Under the line-break condition it will be seen that when a box is actuated to transmit a call, the impulsing circuit is via the operated earthing contacts at the box and the earth connexion on operated contacts EW1 at the fire station. The circuit is completed via line A or line B depending upon the particular box operated and the location of the line disconnexion. It will be observed that on calls transmitted in the normal manner round the loop, and also on calls transmitted during a break in the line via earth, the impulses pass through both the gong and the tape puncher. Relay E normally remains inoperative, but, in the event of an earth fault occurring, this relay operates and gives a warning signal. It will thus be seen that electrically, at any rate, the system is under continuous and perfect supervision. No matter what kind of line fault occurs not only is the fact made known at the fire station, but the system is kept working and no calls from the street boxes can be lost. This is true even in the case of the most exacting fault of all, namely a call from a box that is completely short-circuited.

Fig. 3 gives skeleton drawings showing the essential mechanical and electrical elements of the street box mechanism, which is spring driven. The act of pulling the handle, after breaking the glass, momentarily operates the tripcam lever and this raises the start lever and withdraws the locking pawl from the slot in the wheel, which immediately commences to rotate. The withdrawal



ESSENTIAL ELEMENTS OF THE STREET BOX MECHANISM

Fig. 3. These skeleton drawings show parts photographically illustrated in Fig. 1. The trip-cam lever raises the start lever and withdraws the locking pawl causing the wheel to rotate. This in turn causes the pulsing contacts to operate and so transmit the box number. The call is recorded on a length of paper tape, dated and perforated, which serves as a reference.

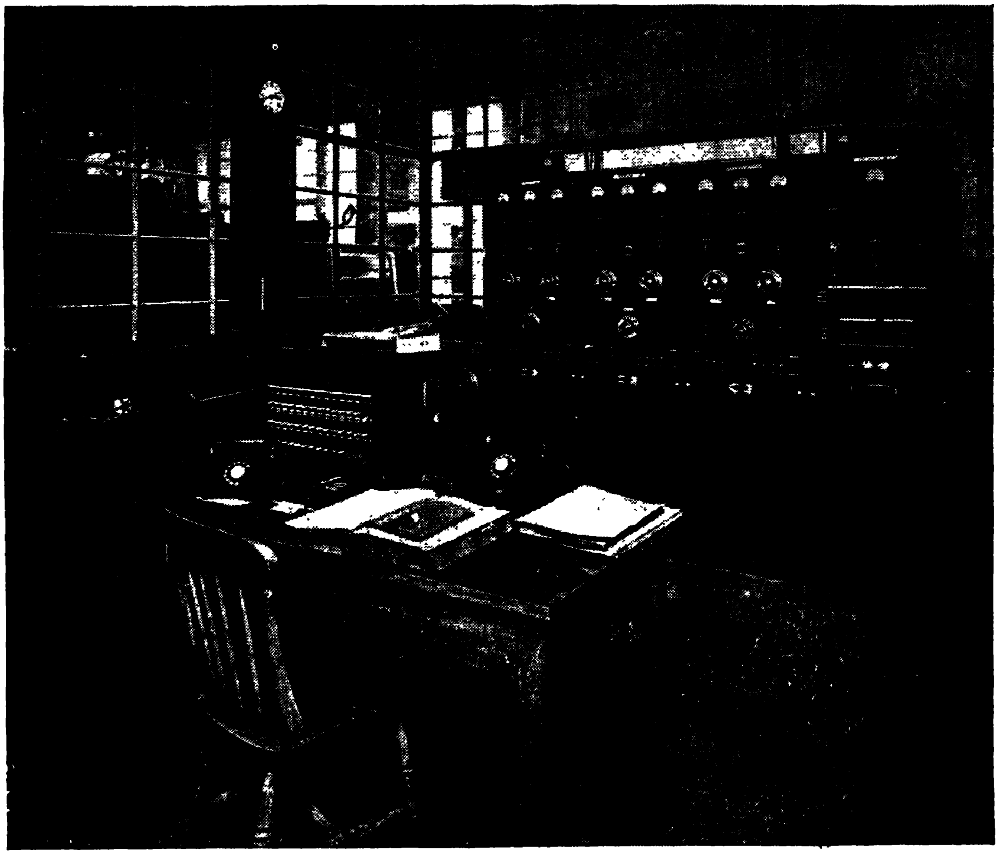
of the locking pawl ensures that the start lever remains operated for at least one revolution of the wheel and during this time the box short-circuiting contacts remain open and the earthing contacts remain closed. The armature resetting and locking pin is also free to ride under the curved portion of the start lever, and will do so if it happens that the coils should fail to hold the armature.

The wheel now being in motion, it will be seen that the tip of the impulsing lever first rides over the long section of the code wheel. This is the testing period of about three seconds and is for the purpose of ensuring that the line is absolutely free from interference by any other street box, one of which might possibly already be transmitting an alarm call. Provided the line is clear, the armature remains attracted and the rotation of the code wheel causes the pulsing contacts to be operated and so transmit the number of the box three times.

On the other hand, if during the testing period the coils become de-energized because some other box is in operation, the armature releases and thus permits the armature resetting and locking pin to ride over the curved end of the

impulsing lever. This has the effect of preventing for the time being the actuation of pulsing contacts of the second box and so avoids interference with the box already in operation. The call must not, of course, be lost and a further rotation of the code wheel has, therefore, to be ensured. This is accomplished in the following manner: It will be observed that so long as the armature is tripped out, the start lever is held operated and locked and the impulsing lever is prevented from transmitting impulses. When, therefore, the transmission of a call has had to be temporarily withheld during one rotation of the code wheel, the mechanism automatically restores the armature, during the last portion of rotation and then remains held by the coils provided there is no further interruption during the three seconds test period. It should be noted that the position of the armature restoring pin is such that the locking pawl safely passes over the slot before the armature is fully restored. When the call has at last been properly transmitted, the armature remains operated and further rotation of the code wheel is arrested.

Electrically the system is perfectly reliable, since full and continuous supervision is obtained and mutual interference between boxes on the same closed loop is automatically prevented.



IN THIS ROOM ALARM CALLS ARE RECEIVED

Fig. 4. Our illustration shows a typical fire station control room. The cabinets at left contain the tape-punching machines and the date and time stamping apparatus. The luminous indicator at the top of the switchboard automatically notifies fault conditions, the right-hand panel containing the firemen's call-bell keys, a two-way key switch being provided for each fireman on duty.

HOW THE WEATHER IS FORETOLD

Anticyclone and depression. How air streams move. The Polar-front theory. How cloud forms are produced. Depression "families." The synoptic chart. Isobars. The rate of travel in high and low pressure systems.

By listening for many years to daily weather forecasts announced by the B.B.C., the public has become quite familiar with the terms anticyclone and depression, or their equivalents, high and low pressure regions, and, in a general way, has come to associate the anticyclone with fine weather and the depression with bad and sometimes very stormy weather, but relatively few people know how forecasts are made.

The variability of our weather is the outcome of the movements of masses of air which arrive over our islands from different regions. Some have their origin in the warmth of the tropics, others in the cold of the polar regions, and, though their routes to our islands may sometimes be very devious, yet, in the main, the warm tropical air moves from the south-west while the cold polar air moves from the north-east, these directions being the natural result of the general atmospheric circulation in the northern hemisphere. These warm and cold air streams have their meeting place in the North Atlantic, chiefly along a belt stretching from the Gulf of St. Lawrence across Iceland to the coasts of Norway, and our islands lie within the southern margin of the belt. This region is likewise the breeding ground of the depressions which provide our bad weather. Formerly a depression or cyclone was regarded as a gigantic eddy or whirl, having low pressure at its centre, round which the winds blew in a counter-clockwise direction, but today it is recognized that the structure of a depression is much more complex. True, the wind *does* move round the low centre, but when the distribution of temperature is examined it is found that in one sector of the depression the air is often markedly warmer than in other sectors, and furthermore that the alterations of temperature are not gradual but often abrupt, and that these abrupt temperature changes are accompanied by equally sudden changes in the direction of the wind. It is evident, therefore, that the air is not rotating as a whole, but that different air streams are taking part.

A NOVEMBER DEPRESSION

Let us examine a concrete case. The map (Fig. 1) shows the position of affairs at 1 p.m. Greenwich Mean Time on a certain November day. The centre of the depression lies off the south-west of Ireland and from this centre two lines have been drawn; a sharp-toothed one stretching down south-westwards, and a round-toothed one running eastwards towards the Thames estuary. Certain weather stations in our islands are indicated by circles with arrows attached to them, and beside each circle is a figure indicating the temperature at that station. To the south of the aforementioned lines the temperatures vary from 53 degrees to 57 degrees Fahrenheit, but north of the lines they are very much lower, ranging from 48 degrees at Yarmouth to 40 degrees at Tynemouth, and to as low as 38 degrees at Valentia, in South-west

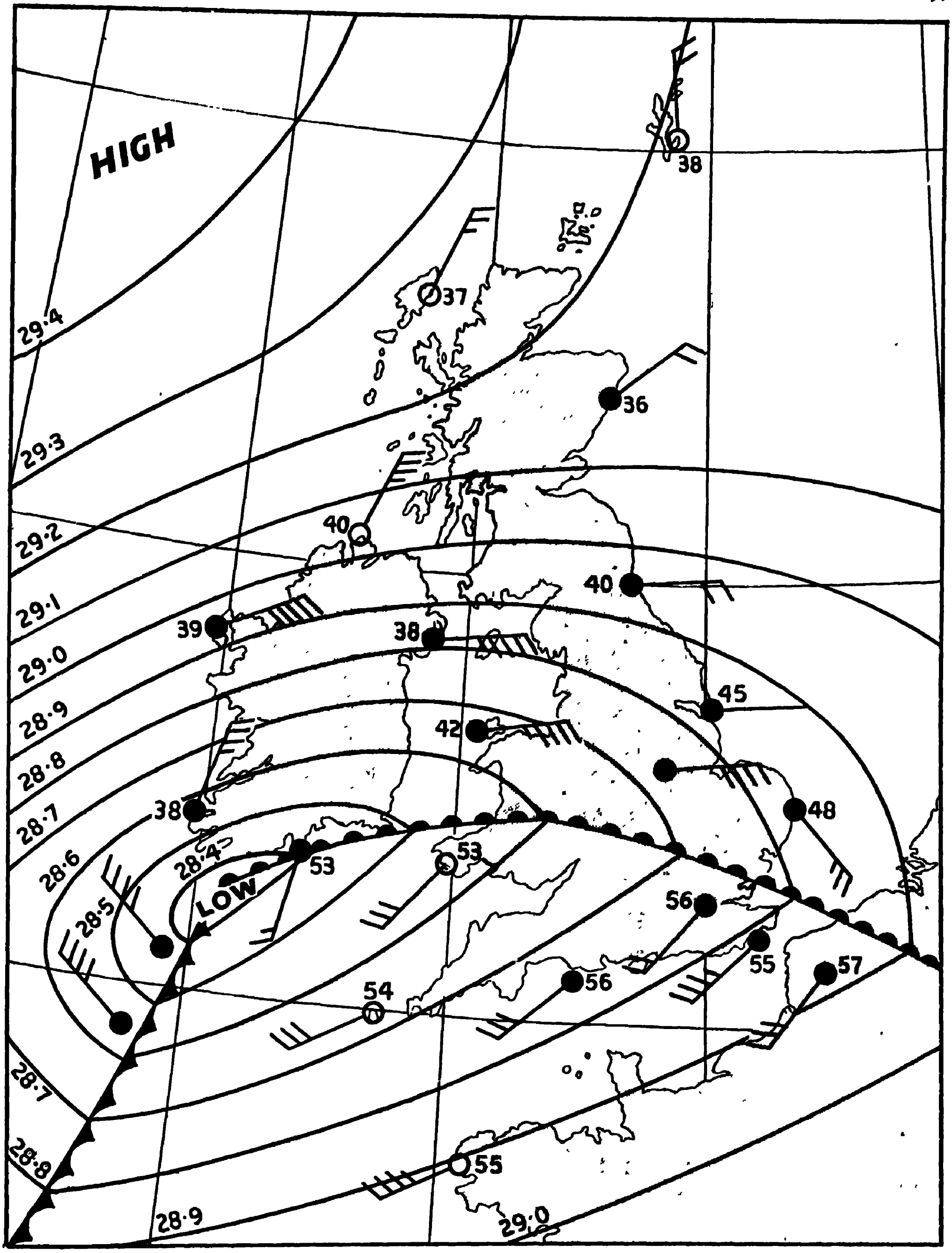
Ireland. This last temperature is all the more remarkable because the temperature at Cork, a relatively short distance away, is 15 degrees higher. Now let us look at the arrows; these arrows indicate the direction and strength of the winds at the time, the arrows blow *with* the wind, towards the stations, and the barbs on their shafts represent roughly 10 m.p.h. for each long barb and 5 m.p.h. for each short one. Within the warm-air sector strong winds or moderate gales of 30 m.p.h. to 35 m.p.h. are blowing generally from the south-west, while north of the lines the winds are even higher, fresh to strong gales of 40 m.p.h. to 50 m.p.h. over the Irish Sea and Ireland, and their directions vary from easterly over England to north-easterly over Ireland. At Valentia a gale is blowing from N.N.E. with a temperature of 38 degrees Fahrenheit, while at Cork there is a gentle S.S.W. breeze and a temperature of 53 degrees.

THE POLAR-FRONT THEORY

During the years 1914-1918 the Norwegian meteorologists V. and J. Bjerknes put forward an explanation of depressions which is called the Polar-front theory, and it is on this theory that the methods of modern weather forecasting are based. Briefly put, the theory states that when warm moist tropical air, moving from a south-westerly direction, finds itself flowing beside cold dry polar air from the north-east, a wide difference exists between the conditions on either side of the boundary between them. This boundary is known as the Polar-front; it is not a vertical wall of separation but an inclined surface of about 1 in 100, sloping upwards towards the cold air, the warm air thus projecting and overlapping over the cold.

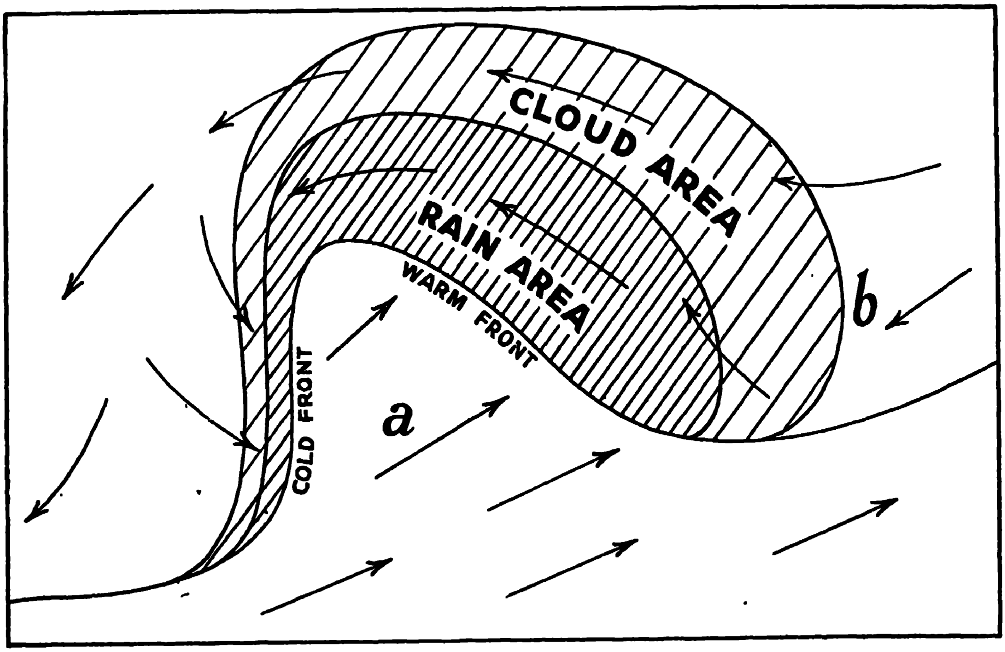
When an undulation or wave-like disturbance occurs in this sloping surface of separation it appears on the ground level as a tongue of warm air projecting into the cold air as shown at *a* in Fig. 2. This tongue of warm air causes the cold air to be diverted and to move round the tongue as shown by the arrows at *b* in Fig. 2, so that eventually it takes the warm air in the rear. Within the tongue the warm air is still moving from the south-westward while the cold air is deflected from its original north-easterly direction, becoming southerly, then easterly, and finally north-westerly in the rear of the warm air. Compare this figure, which is, of course, an idealized diagram, with the actual situation shown on the map in Fig. 1, and the resemblance of the actuality to the theory becomes at once apparent.

Because the round-toothed line indicates the intruding warm air it is called the warm front, and because the sharp-toothed line heralds the advent of the cold air it is termed the cold front. Now what is happening at these fronts where the winds oppose each other? At the warm front the south-westerly air is warmer and therefore lighter than the cold air, and is compelled to rise upwards over the cold air. On rising in this manner, the warm air expands because of the reduced pressure, the expansion results in cooling and the cooling brings about the condensation of the water vapour which the warm air holds in considerable quantity. Thus a widespread sheet of cloud, like a wedge, is formed, projecting over the cold air about 500 miles in advance of the warm front. The advancing edge of this cloud-sheet is about five miles high, and is composed of the wispy *cirrus* or mares'-tail cloud (Fig. 4). This is succeeded by gradually thickening and darkening cloud till about half-way across the wedge the cloud becomes the greasy-grey *alto-stratus* two or three miles high (Fig. 5); this in turn continues to increase to the leaden-grey *nimbo-stratus*



WHAT HAPPENS WHEN COLD FRONT MEETS WARM FRONT

Fig. 1. This map, made in November, shows diagrammatically the conditions created by a depression, whose centre lies off the south-west coast of Ireland. The round-toothed lines indicate the warm air, the sharp-toothed line, the advent of cold air. Where they meet cloud and rain are caused. Weather stations are marked by circles. At those blacked in, snow and sleet are falling and the temperatures are shown by figures ranging from 53 to 57 degrees Fahrenheit south of the lines but much lower north of them. The barbed arrows show the strength and direction of winds, about 10 m.p.h. for a long barb and 5 m.p.h. for a short. The figures at the left denote pressure values.



SIMPLIFIED PLAN OF A DEPRESSION

Fig. 2. This diagram illustrates the actual situation shown in Fig. 1. A tongue of warm air projecting into the cold air at (*a*) causes it to be diverted and to move round the tongue at (*b*), eventually taking warm air into the rear. The arrows indicate the movement and direction of surface winds.

and scud from which rain begins to fall, and which, in the neighbourhood of the warm front, may be as low as a thousand feet or so, with steady rain. The width of the rainbelt may be 100 to 200 miles in a normal depression.

Along the line of the cold front the cold air is advancing and is ploughing up the lighter warm air more steeply and violently than is the case at the warm front. Here also a cloud and rain belt are formed, but it is very much narrower than that belonging to the warm front, while, because of the greater steepness and violence of its ascent, the rain is produced in heavy showers and is of shorter duration. The cloud in this rainbelt appears sometimes as a very dark ragged-edged band across the sky (Fig. 6), and sometimes, when thundery conditions accompany the cold front, a wall of massive *cumulo-nimbus* (Fig. 7) may precede a squall and change of wind.

These two fronts do not remain separated. The cold air in the rear advances more rapidly than the warm air, and eventually the cold front overtakes the warm front and the mass of warm air is lifted off the surface. When this occurs the depression dies out and the warm air is said to be occluded. Such depressions have a habit of occurring in families, that is to say that four or five of them may follow in succession.

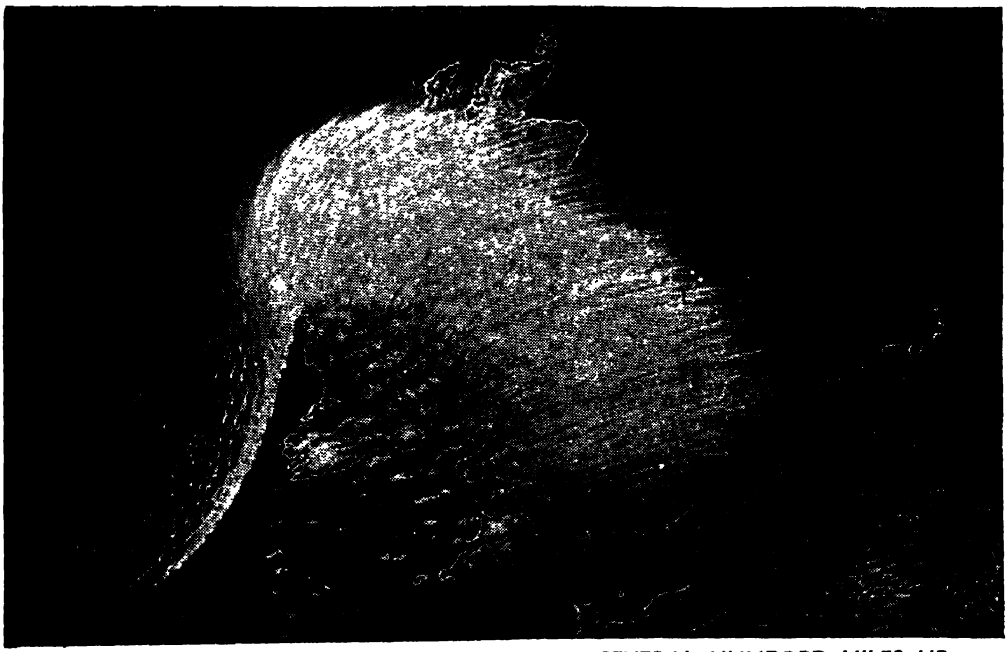
TASK OF THE FORECASTER

It is the task of the forecaster to anticipate as far as possible the formation of these depressions and to judge the further course and development of those already existing. For this purpose very elaborate maps called synoptic charts, are drawn every few hours at the forecasting stations; upon these maps are entered all the various data which are simultaneously recorded and reported by the numerous observing stations which form a network throughout the

whole region under survey. Such data include observations of the pressure, the amount and nature of its changes during the preceding three hours, the temperature and humidity of the air, the direction and force of the wind, the present and past weather, the type of cloud together with its height and amount, the degree of horizontal visibility and the state of the sea. These observations are entered on the map in a special code of symbols beside each reporting station, and from the observations of pressure the isobars are drawn on the map. An isobar is a line drawn through those places where the pressure readings are the same. When this is done the result is a series of lines running over the map in closed or open curves and resembling the contour lines indicating heights on an orographical map. Figures denoting the pressure values are entered as shown on the left-hand side of the map (Fig. 1), where the figures 29.4, 29.3, etc., indicate the pressure readings in inches and tenths. The highest reading, 29.4 in. lies off the north-west of Scotland, while the lowest, 28.4 in. is found in the centre of the depression. This indicates a slope or gradient of pressure from the high, downwards to the low, and is like the slope from a hill to a valley.

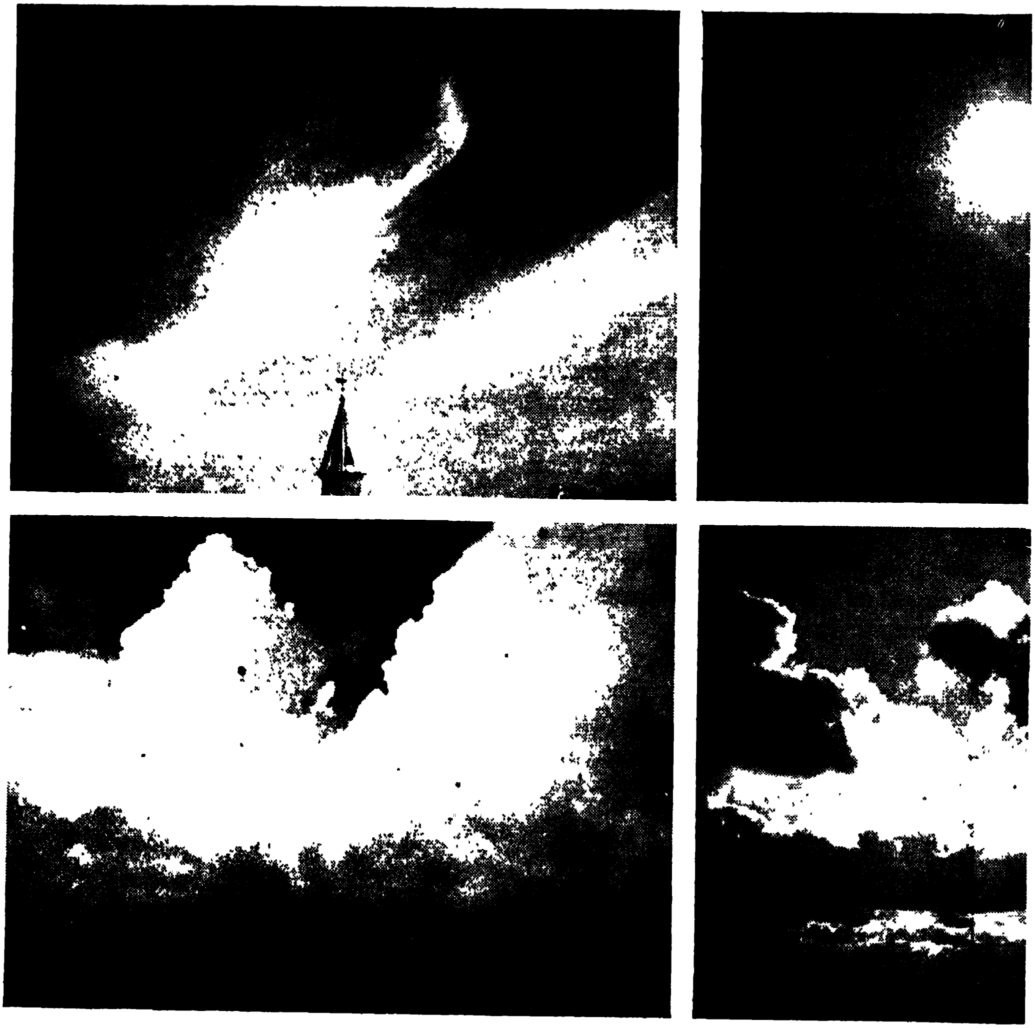
WHAT THE ISOBARS SHOW

When drawn the isobars show at a glance the distribution of pressure and, in conjunction with the winds reported from the various stations, they reveal one of the fundamental facts concerning the weather, namely, that in the northern hemisphere the winds flow along the isobars in a counter-clockwise direction round a low, but in a clockwise direction round a high, with the modification that the directions are inclined across the isobars a little inwards towards the low centre but a little outwards from the high region. When the isobars are closely packed on the map, or, in other words, when the pressure gradient is steep, the



HOW A DEPRESSION WOULD APPEAR FROM SEVERAL HUNDRED MILES UP

Fig. 3. This depression centred over north-west Ireland is travelling towards the Skagerrak. Over Scotland the weather will be rainy, over England wet, then warm, finally cool and fair.

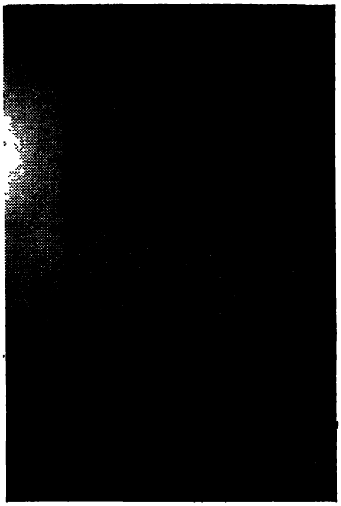


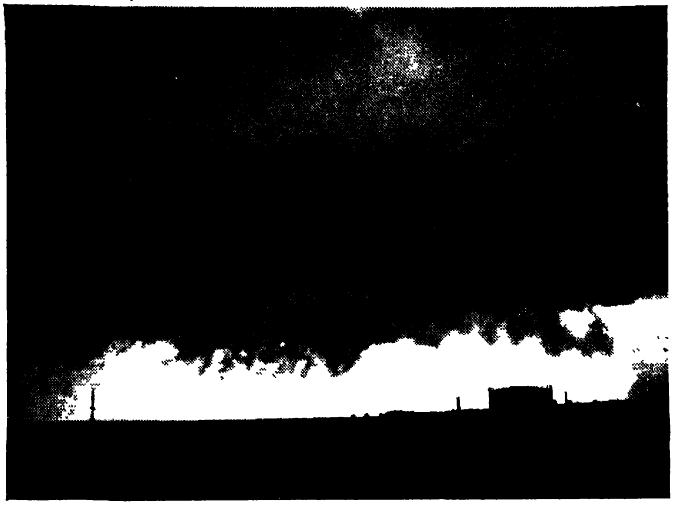
HOW TO READ THE WEATHER SIGNS

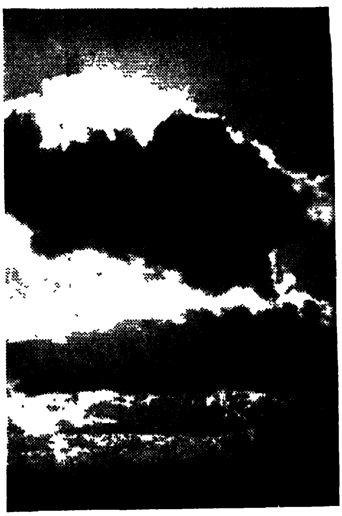
Figs. 4 to 9. Wedge-like, wispy-edged sheets of cloud known as cirrus tufts are the forerunners of a depression (Fig. 4, top left). These, darkening to alto-stratus (Fig. 5, top centre), become the grey warning of nimbo-stratus from which steady rain falls. Short heavy showers often appear as

winds are strong, but when widely separated the winds will be light.

The next stage is to identify the fronts on the synoptic map by examining also all the other observations and noting where marked differences occur. These may be differences of temperature and wind direction, as in Fig. 1, the nature of the pressure changes taking place at the time, the disposition of the various cloud types, and the occurrence of rain in some areas together with data regarding the amount of water vapour in the air. When a depression exists in its full vigour, as in Fig. 1, the position of the fronts is obvious, but in the great majority of cases the depressions occurring over our islands are already in process of filling up, or are already occluded. In addition, further changes will be produced in the temperature of the surface layer by its passage from sea to land or over mountainous country, whereby the original differences may become sup-







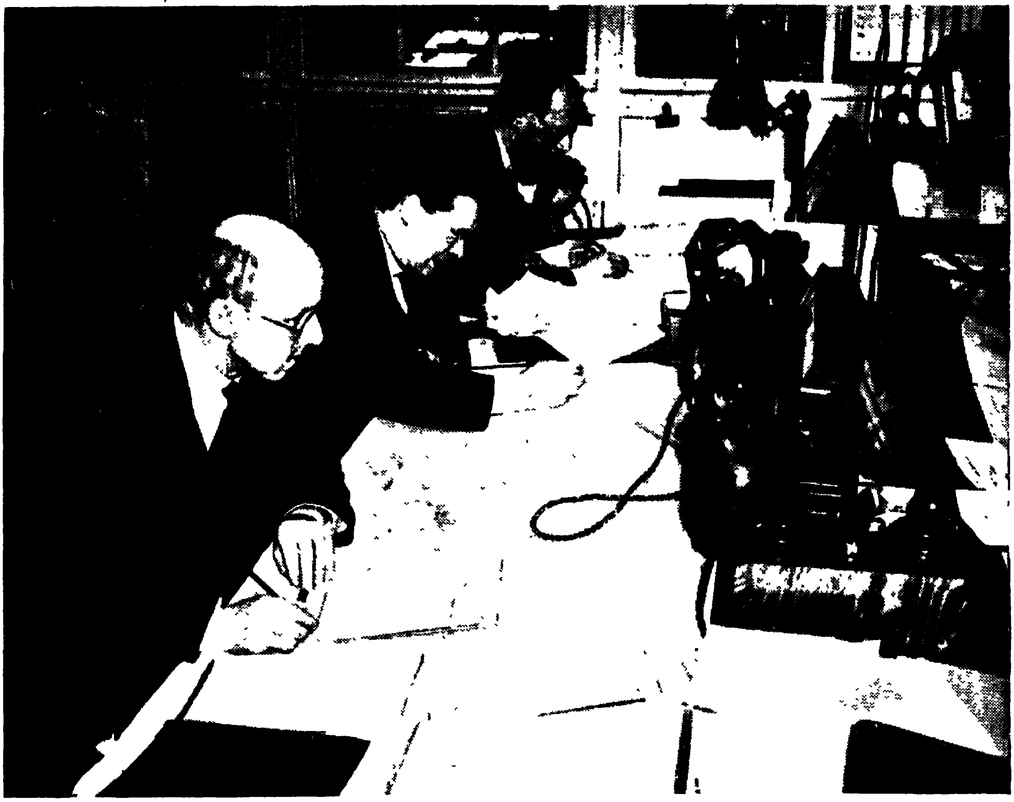
IN VARIOUS TYPES OF CLOUD

dark, ragged-edged bands across the sky (Fig. 6, top right), and when accompanied by thundery conditions, as cumulo-nimbus (Fig. 7, bottom left). With the passing of a depression, cumulus (Fig. 8, bottom centre) is characteristic. On its southern margins, alto-cumulus appear (Fig. 9, bottom right)

pressed. The problem of identifying the fronts then becomes one of considerable difficulty and it is here that observations of temperature and humidity made in the upper air by means of aeroplane ascents are a better means of discriminating between the various air masses.

Once the whole situation has been mapped out, the forecasters, taking account of the direction and rate of travel of the pressure systems, and of the nature of the surfaces over which they are likely to move, issue their forecasts, based on theoretical considerations and also on their past experience.

High and low pressure systems travel, the former usually very slowly, the latter sometimes rapidly, in summer the average speed of a depression is 15 m.p.h. to 20 m.p.h., in winter 25 m.p.h. to 30 m.p.h. The example given in Fig. 1 moved from South-west Ireland to the Straits of Dover at 32 m.p.h., and from there to Heligoland Bight at 25 m.p.h



IN THE FORECAST ROOM AT THE METEOROLOGICAL OFFICE

With their charts before them, forecasters are here seen at the work which in normal times gives the public an accurate description of coming weather. Theory, past experience, and actual data of the pressure system as described in our article, are all used to solve the daily problem.

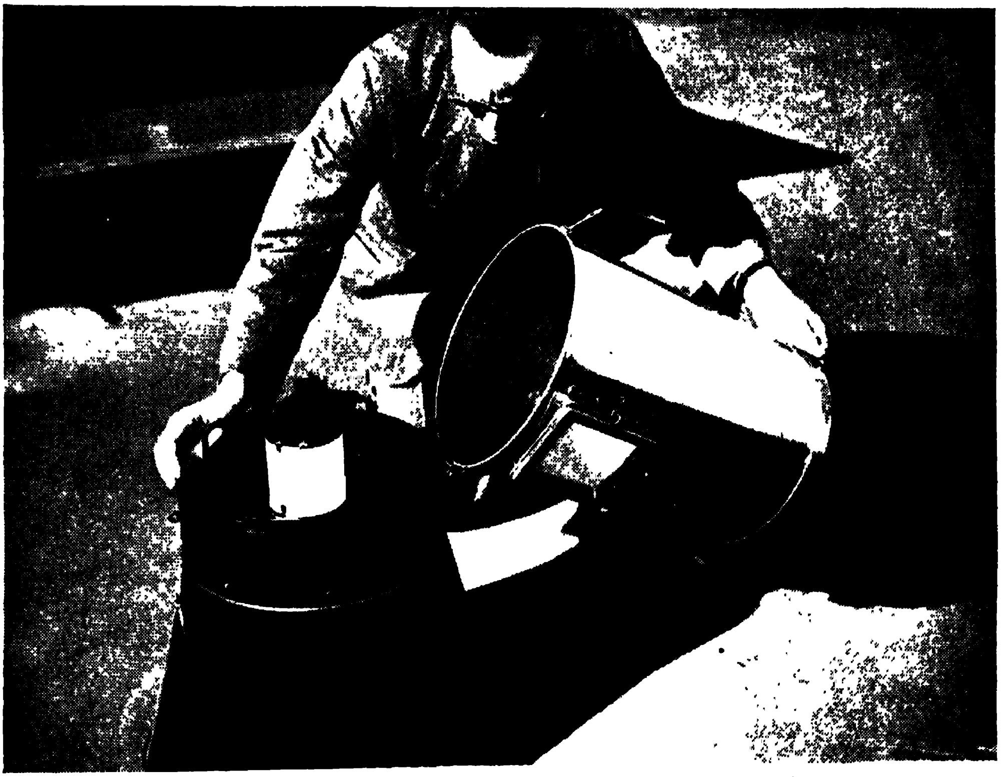
Depressions may be anything up to 1,000 miles in diameter, and they may move in almost any direction, but do so chiefly from south-west to north-east. In the course of their passage the pressure systems carry their weather with them. Within their rainfall belts more rain will fall on the higher ground than on the lower because of the additional expansion and cooling caused by the air having also to rise over the mountains. Evidence of this is shown by the fact that the annual rainfall in the east of our islands is from 25 in. to 30 in., whereas it exceeds 150 in. in the west.

Anticyclones are regions of calms or gentle winds, usually, but not always, of fine weather; sunny and warm in summer; cold in winter, sometimes bright, though very often cloudy and foggy.

After the passing of a depression, and sometimes within anticyclonic regions, especially in summer, the ordinary *cumulus* (Fig. 8) is a characteristic cloud, while on the southern margins of a depression mackerel or *alto-cumulus* skies (Fig. 9) are frequently in evidence.

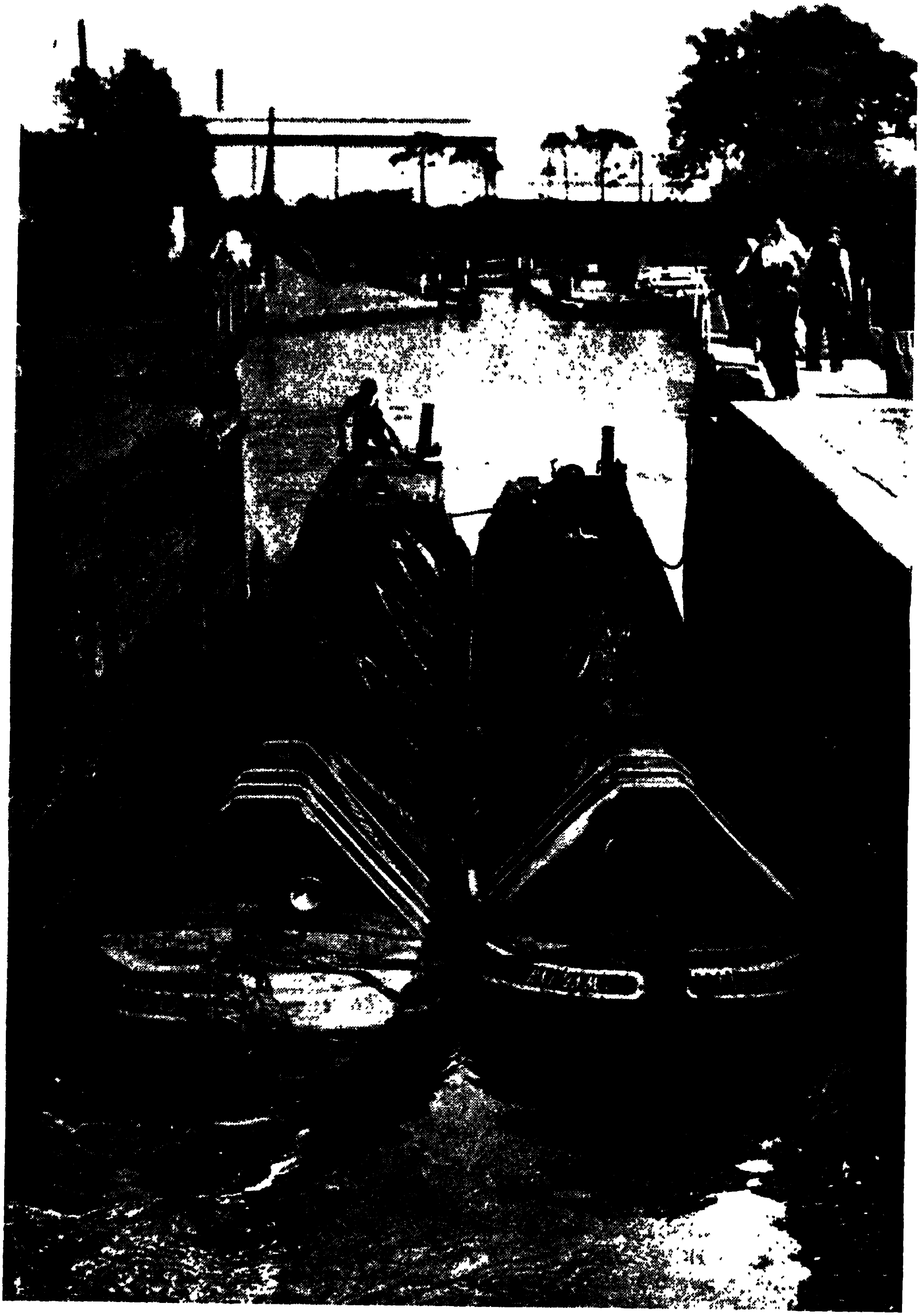
Fig. 3 is an attempt to show how a moderately sized typical depression over our islands would appear if seen from a height of several hundred miles above.

The depression is centred over north-west Ireland, and is travelling towards the Skagerrak. Weather over south and central England and Ireland will first be wet and cool, then cloudy and warm, and finally cool and fair. Over Scotland it will be cool and rainy



HOW WIND SPEEDS AND RAINFALL ARE MEASURED

The anemometer, shown top left, measures the force and velocity of the wind. The pressure of wind on a plate attached to a spiral spring is transmitted to a pencil which leaves its trace upon paper moved by clockwork. There are several types of this instrument. The direction of wind in the upper air is also determined by balloons as shown top right, and this information is of value to aircraft. The illustration above shows a self-recording rain gauge. These give a continuous record of rainfall, showing the amount of fall for each hour or shorter period.



ENTERING THE LOCK CHAMBER AFTER EQUALIZATION OF WATER LEVELS

The canal lock, essentially, is a method of negotiating a rise or fall in ground level. This is effected by floating craft within a closed structure, equalizing water levels outside and in.

HOW CANAL LOCKS WORK

Why canal locks are needed. Their construction. Types of lock gate—single leaf, trap gate, lift gate and balanced sector gate. Admitting and emptying the water. Arrangement of locks in flight. Types of lift.

CANALS, important means of transportation as they are, differ from road and rail in not being able to climb hills or to descend valleys so easily. Surfaces suitable for wheeled vehicles can be laid on reasonable gradients, but canal water, of course, cannot perceptibly slope, though if suitably isolated from stretch to stretch along its course, it may be made to assume widely different levels. Ground obstructions are sometimes avoided by passing through cuttings or tunnels, or along aqueducts, but a common method of negotiating a rise or fall in ground level is by dividing the waterway into successive lengths, at different levels, and providing suitable means to lift or to lower passing craft from one level to the next. This can be done either by floating the craft within the walls of a closed structure and varying the water level from the lower to the higher level (or vice versa), or by moving the craft bodily by means of a suitable form of lift. The first method is more usual, and is to be found in the ordinary canal lock, but in a number of cases lifts are used, for the most part however, on Continental canals, which are larger and more widely developed than in Great Britain.

ESSENTIAL PARTS OF A LOCK

The essential parts of a lock are the fixed permanent lock chamber, the gates for admitting the craft—which, when closed, isolate the enclosed body of water—and the sluices for filling the lock with water from the higher level or releasing it eventually to the lower level as circumstances require. These are shown diagrammatically in Fig. 1. There are many varieties of lifts, but in all cases the work of lifting the craft is reduced to a minimum by balancing its weight with counterweights, or by constructing duplicate lifts arranged so that one is being lowered while the other is being raised, a link rope maintaining the balance between the two.

SIZE OF LOCKS

Locks vary greatly in size, being built to suit the usual size of boat or barge using the canal. The smallest are about 75 ft. long and 7 ft. wide; the largest locks on the Manchester Ship Canal are 600 ft. long and 80 ft. wide. Large or small, however, they are nearly all built on the same principle, having massive brick or concrete side walls to resist the heavy earth pressure behind them when the lock is empty, an invert, or arched floor to resist pressure beneath, and a headwall at the upper end providing a step between the two levels. At each end of the lock a solid masonry or concrete sill is formed, the one at the upper end abutting on to the headwall (Fig. 1). The sills are usually of V formation, the front edges (called mitres), where the gates rest when closed, being made of dressed stone, cast-iron or hard timber. At the sides of the sills recesses are left in the lock walls for the gates to lie in when open, the hinge end of the recess being fitted with a curved cast-iron or masonry wearing face, known as a quoin, in which the heel post of the gate revolves, and which also provides

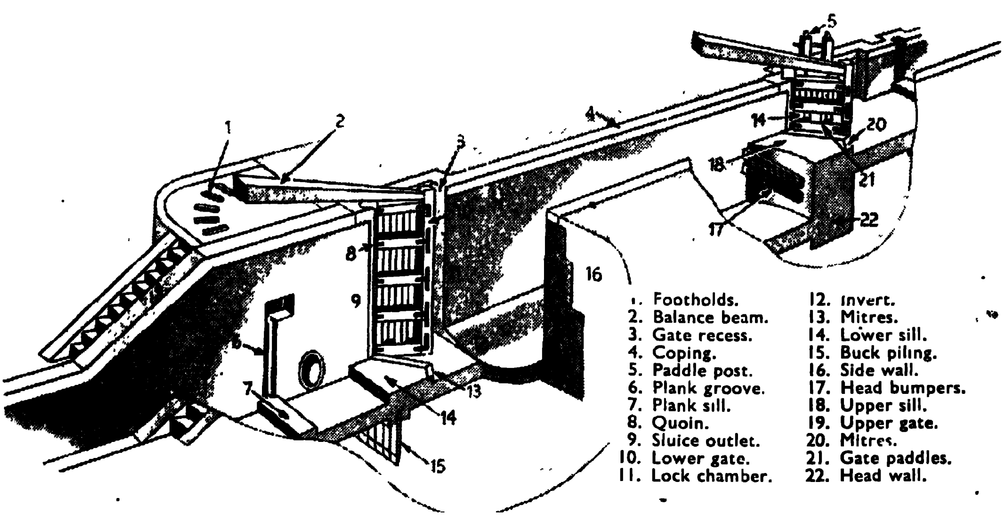
a watertight sealing face together with the mitres when there is water pressure on the back of the gate. Additional sills are provided at the ends of the lock with grooves in the side walls to take planks laid one above the other horizontally. These are placed in position when the lock requires pumping dry for repairs.

LOCK DEPTHS

The overall depth of the lock depends on the difference between the two water levels, but in order to keep the size of the walls and gates within reasonable dimensions this difference, or rise does not usually, for British canals at any-rate, exceed about 10 ft. In fact 7 ft. is a very common figure, but with the larger locks found on the Continent a rise of double this amount or more is often found. The greater the rise of individual locks, of course, the fewer locks will be needed to attain a given total difference of level, but large rises are only structurally economical in large locks, where the whole scale of the work justifies the heavier type of lock construction.

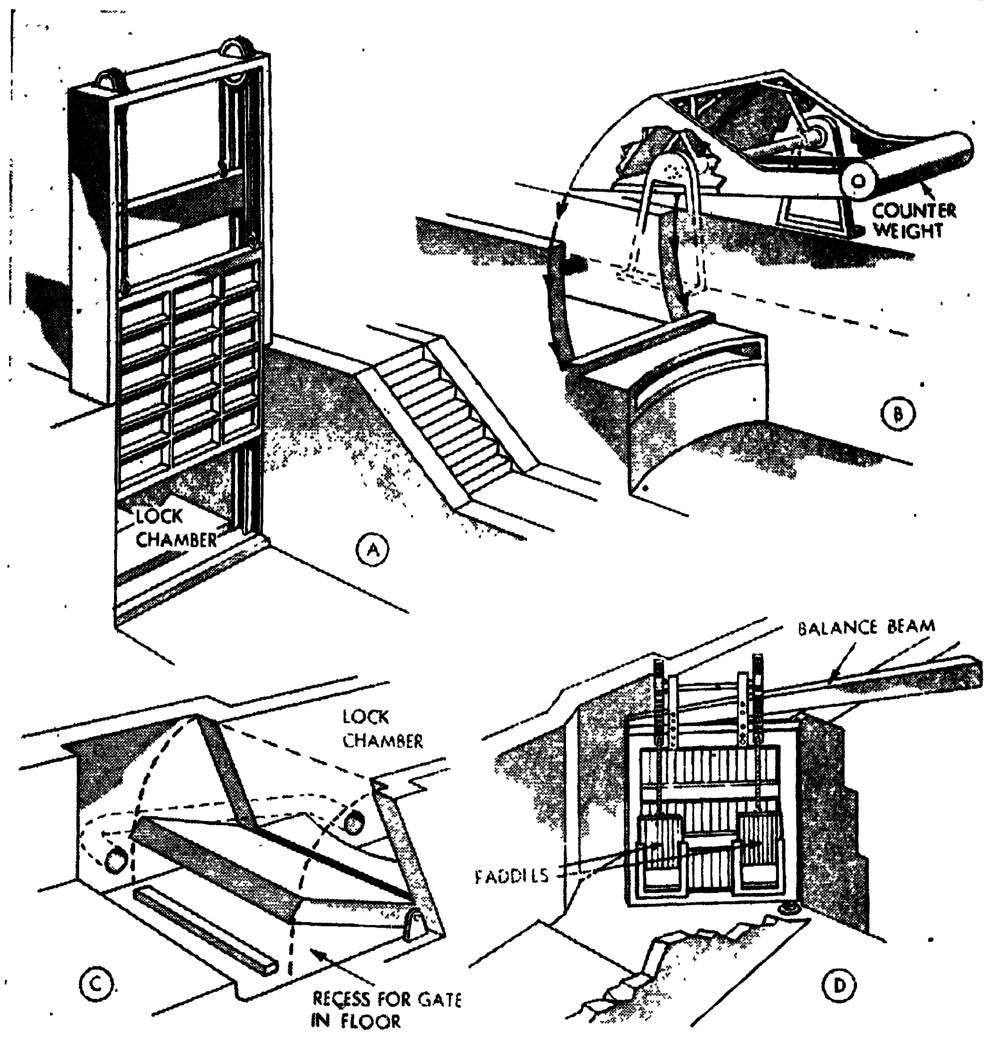
Some representative modern locks built for English inland canals were those constructed about 1933 on the Warwick section of the Grand Union Canal to replace the older narrow locks during a general widening and improvement of the section (Fig. 3). These locks are 83 ft. 6 in. long and 15 ft. wide internally, the deepest having a rise of 8 ft. $4\frac{1}{2}$ in. With a depth of water on the sills of 6 ft. and a coping level of 1 ft. above water this gives a total height of lock wall of nearly 15 ft. 6 in., the gates at the lower end being of course, approximately the same height.

The gates of the ordinary canal lock are invariably constructed of timber, the elasticity, durability and freedom from corrosion, rendering this material superior to iron or steel. In larger locks, as for example on ship canals, the greatly increased stresses can only be met by using gates built up from steel angles and plates, the hollow construction providing buoyancy which relieves the



ESSENTIAL PARTS OF A CANAL LOCK

Fig. 1. Nearly all canal locks are built on the same principle having massive side walls—an invert, or arched floor, to resist pressure beneath, and a headwall providing a step between the two levels. At each end is a sill, at whose front edges (called mitres) the gates rest. At the side of the sill is a recess with a curved face, known as a quoin, in which the heel post of the gate revolves. The heavy balance beams help to balance the gates and are also used as levers to open and close them.

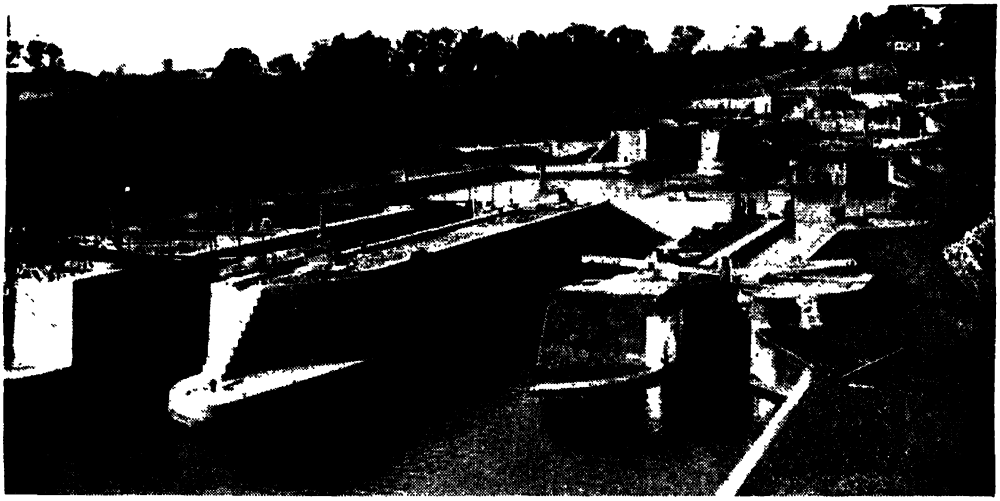


FOUR DIFFERENT TYPES OF LOCK GATES

Fig. 2. Type A is a form of lift gate which can be raised against water pressure. Type B is a balanced sector gate which swings over. Type C is a trap gate which can be raised or lowered by filling an internal buoyancy chamber. Type D is a single leaf gate often used at the upper end of narrow locks where the water pressure is fairly small. It is fitted with balance beam and paddles

load on the hinges. In any case the gates must be stoutly constructed to withstand blows from craft entering and leaving the lock quite apart from the normal loads and stresses due to water pressure. Fig. 1 also shows the heavy balance beams which not only help to balance the gates and thus relieve the load hanging in the collars, but are also used as levers to open and close the gates by manual power. In addition to the common mitring gates described above, there are several other forms used under special circumstances, and some of these are shown in Fig. 2.

Type A gives an idea of one form of lift gate, the advantage being that it can be raised against water pressure and can thus be used for passing a large quantity of water directly through the lock. This type has recently been used for flood relief purposes on the new locks on the



CANAL LOCKS OLD AND NEW

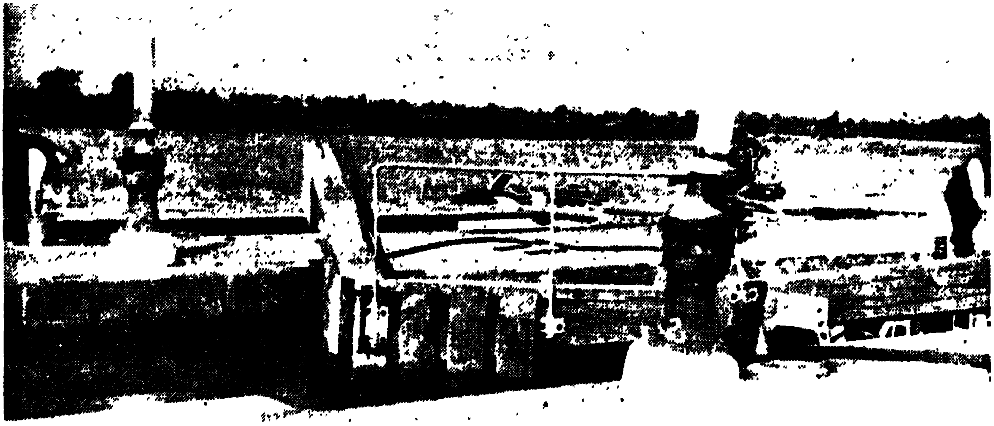
Fig. 3. This view of a stretch of the Grand Union Canal between London and Birmingham shows both the traditional type of English canal lock and the new and enlarged locks which are now replacing them. The new locks allow the use of large barges and accelerate the canal traffic.

River Nene below Northampton. Type B is a balanced sector gate which can also be used for flood control purposes, but is generally more complicated and expensive than other types.

The next diagram, Type C, shows a trap gate which lies flat on the bottom of the head-bay when open, and is hinged about a horizontal axis near the sill. This form is very convenient when of hollow steel construction as it can be raised and lowered simply by exhausting or filling an internal buoyancy chamber with canal water by means of a valve.

Type D is a simple single leaf gate often used at the upper end of narrow locks where water pressure is small. Minor variations of these types are in use on Continental canals, but essentially they would come under one or other of the headings enumerated here.

A very interesting and important

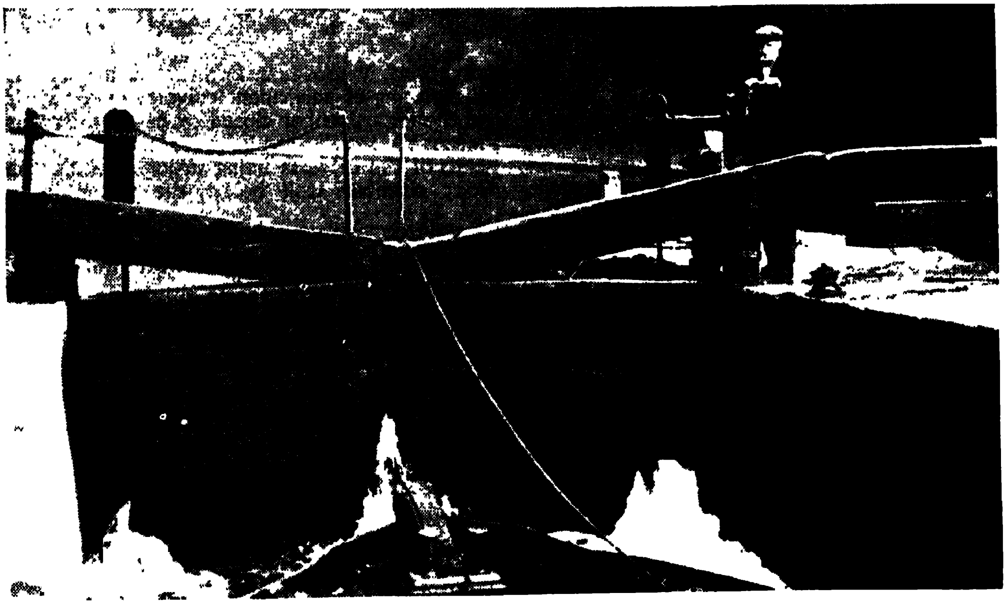


ENCLOSED SLUICE GEAR

An improved type of enclosed sluice gear is illustrated here, and may be compared with the simple form whose operation is shown in Fig. 4. It is now employed at many English canal locks.

feature of all locks is the means employed for admitting and emptying the lockage water. The simplest method is to form an opening in the gate and to cover it with a movable paddle operated by rack and pinion (Fig. 4). At the upper end of the lock the bottom of the gate is usually some distance above the lower water level, and unless care is taken in directing the flow of water from the openings it may easily swamp

In place of a plain flat paddle, susceptible to wear and inevitably liable to friction in working, a cylindrical sluice may be used (Fig. 7). A much smaller movement suffices to open it fully—only a quarter of the height of a flat paddle of equal area—and friction is entirely eliminated. For larger locks the flow of water into the lock chamber from the culverts is distributed to reduce turbulence and possible damage to the



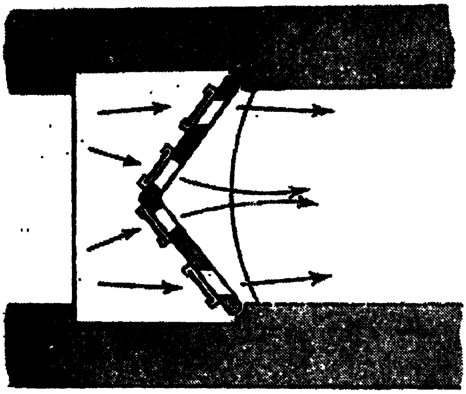
HOW LOCKAGE WATER IS ADMITTED AND EMPTIED

Fig. 4. The simplest way of admitting and emptying the lockage water is by forming an opening in the gate, which is covered with a movable paddle operated by a rack and pinion as shown above.

the boats lying in the lock. For this reason the paddles must be divided and kept small as shown in Fig. 5. A much more efficient type is next shown in diagram (Fig. 6), permanent culverts being formed in the walls of the lock chamber and closed by paddles at the entrances. As the other ends of the culverts can be brought into the chamber well below water level the paddles can be made quite large without fear of undue disturbance of the lock water when filling; greater speed of operation is therefore permissible by this means.

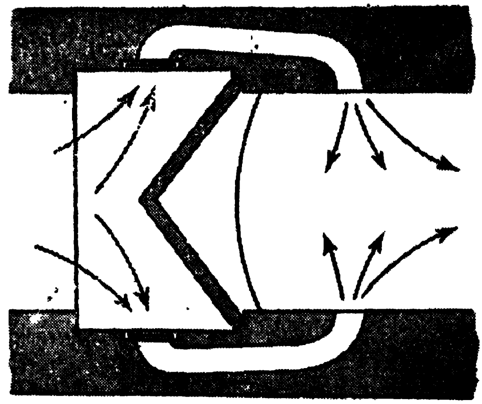
craft. This can be done by one or other of the methods shown in Figs. 7 and 8.

One of the biggest problems in designing locks is to find sufficient water to operate them, or alternatively so to plan them that a minimum quantity of water is used at each locking. It is obvious that with the ordinary type of lock the volume contained between the upper and lower gates and between the two levels is used and lost each time a boat passes through the lock—lost, because once used it cannot be recovered except by the expensive operation of



WHY PADDLES ARE DIVIDED

Fig. 5. Gate paddles are divided and kept small as shown in this illustration in order to keep the flow of water under control. As the bottom of the gate is usually above low-water level, boats might otherwise be swamped by the unrestrained flow of water from the openings.



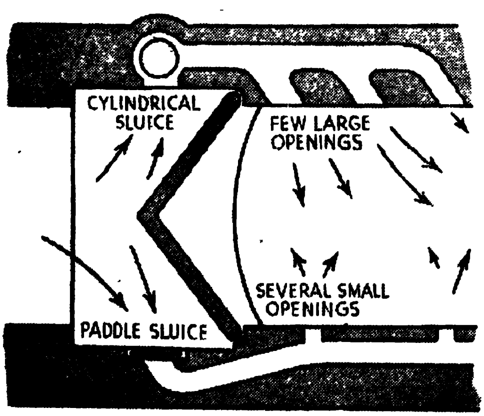
USE OF CULVERTS

Fig. 6. An improvement on the small paddle is the placing of permanent culverts in the walls of the lock chamber closed by paddles. By this means the paddles can be made large, the other ends of the culverts being brought inside the lock chamber well below the water level.

pumping back again to the higher level. The commonest method of overcoming this difficulty is to use side ponds, or a set of auxiliary shallow basins constructed alongside the lock chamber and connected with it by culverts and sluices. The top portions of the water are then run off into the side ponds in sequence (Fig. 9), only the bottom portion necessarily being run out to waste. The water stored in the ponds is now available for partially filling the lock ready for the next operation; only the balance will then require to be drawn from the top level for the complete cycle. It will be seen from the diagram that with two ponds half the water is thus conserved; with more ponds in the series the economy would be greater still.

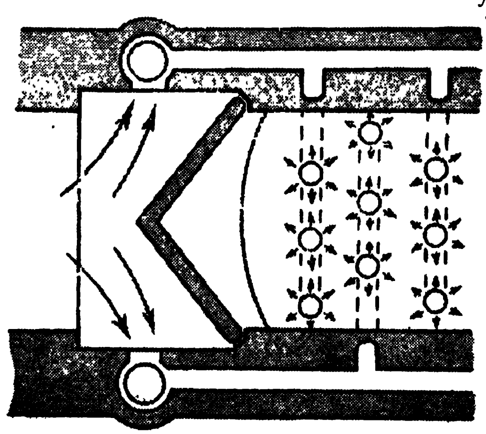
Where traffic is sufficiently heavy to justify the construction of double or duplicate locks (Fig. 10), one lock chamber can be made to act as a side pond for the other if desired, thus allowing for a considerable measure of saving without requiring extra construction.

If water is very scarce where a flight of locks must be constructed it normally



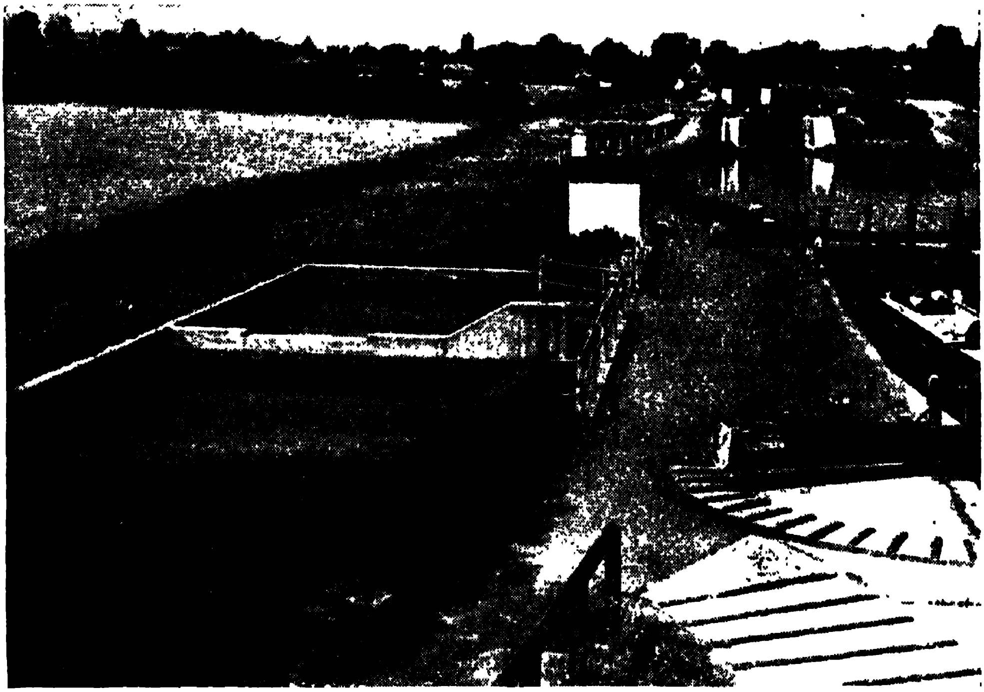
THE CYLINDRICAL SLUICE

Fig. 7. An alternative to the plain flat paddle, which smaller movement suffices to open



DISTRIBUTING THE WATER FLOW

Fig. 8. In larger locks the flow of water from the culverts is distributed by the method shown.

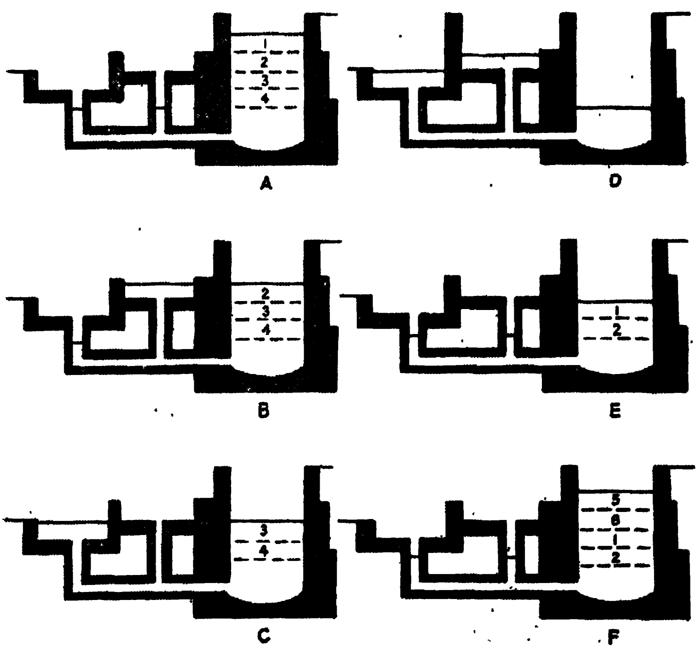


STORAGE OF WATER IN SIDE PONDS

To conserve water, side ponds are constructed alongside the lock chamber and connected with it.

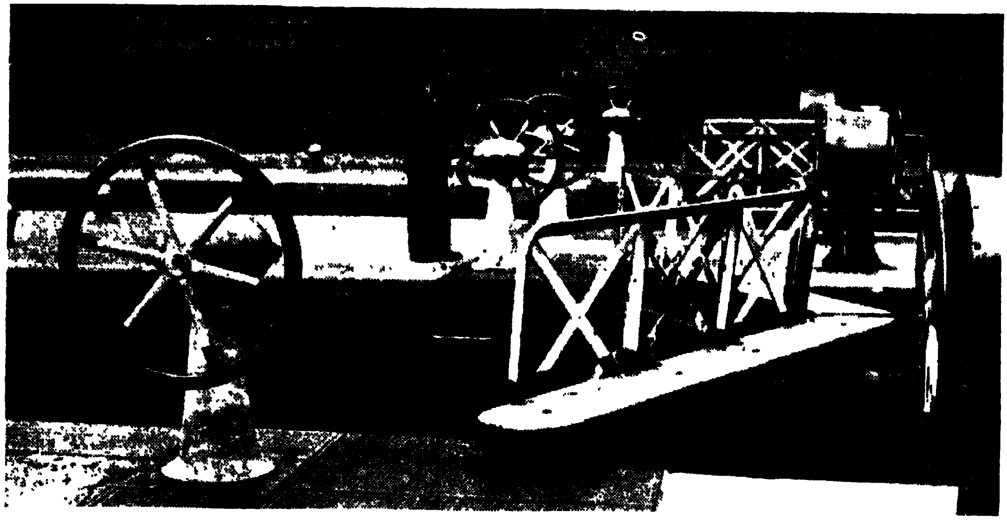
means that a large number of locks of small rise must be used in order to effect the smallest possible consumption of water.

The normal arrangement of locks in a flight is as shown at Fig. 11, A, ample space being left in the intermediate pounds for craft to pass and to provide a water content sufficient to avoid undue fluctuations in level when filling or emptying the locks. If the required average gradient is too steep for this, staircase



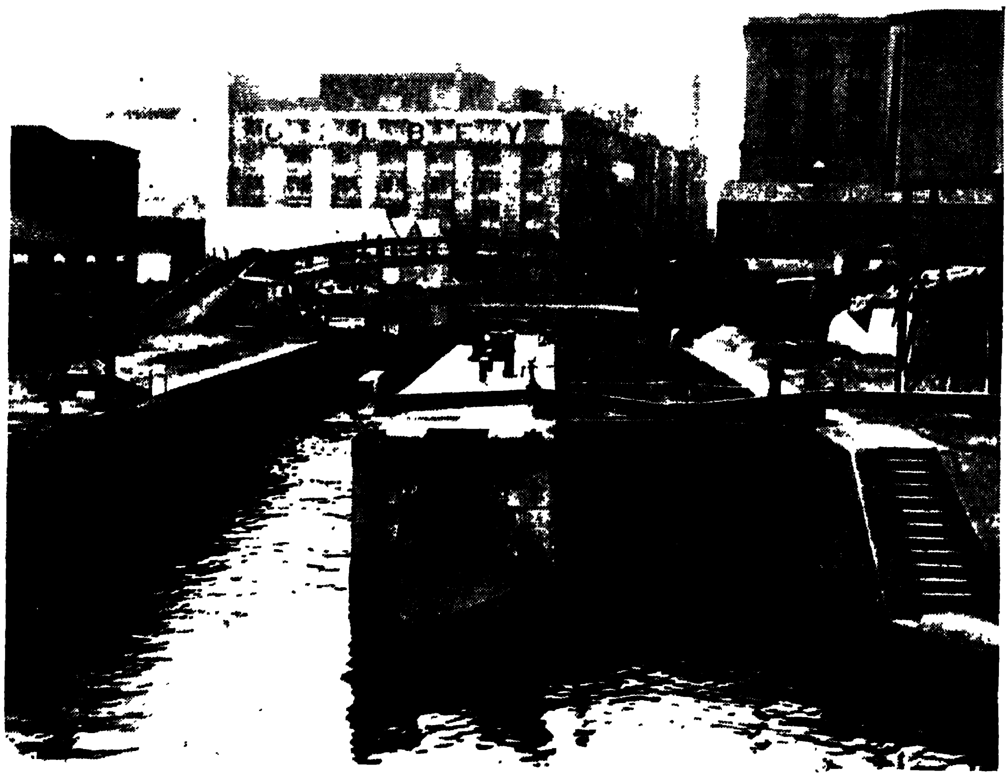
HOW THE USE OF SIDE PONDS CONSERVES WATER

Fig. 9. This diagram shows how successive water levels are run off to the side ponds, the lock being then refilled with a minimum of new water.



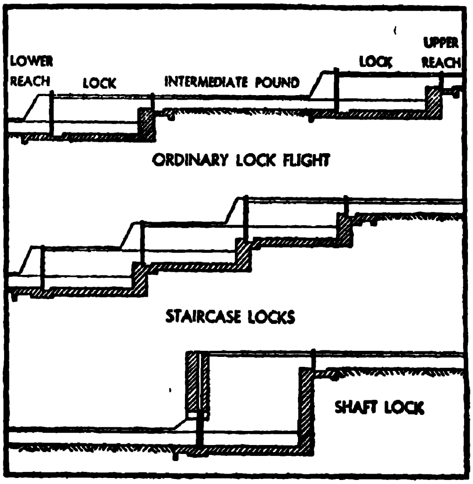
SLUICE OPERATING GEAR

This photograph shows sluice-operating wheels and gearing at the Brentford locks on the Grand Union Canal. This kind of gear is a variation of the types previously shown on pages 246 and 247.



DUPLICATE LOCKS ARE USED FOR HEAVY TRAFFIC

Fig. 10. When traffic is heavy, double locks may be used, as here in a district of London. One lock chamber can be used as a side pond for the other, thus allowing for a considerable measure of saving without requiring extra construction. In Britain the lock system is improved, without adding costly and elaborate new devices, but by attention to economy in the existing method.



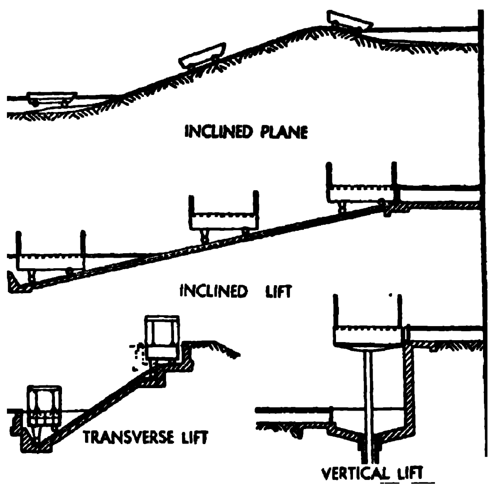
HOW LOCKS ARE ARRANGED IN FLIGHTS
Fig. 11. A normal arrangement of locks in a flight is shown above at (A). This can be converted into a staircase construction for steeper gradients (B), halving the number of gates required, or it may be further telescoped into a single deep lock (C), side ponds being used in this case, in order to minimize water consumption.

construction as shown in Fig. 11, B, is often adopted so that only about half of the number of gates are required.

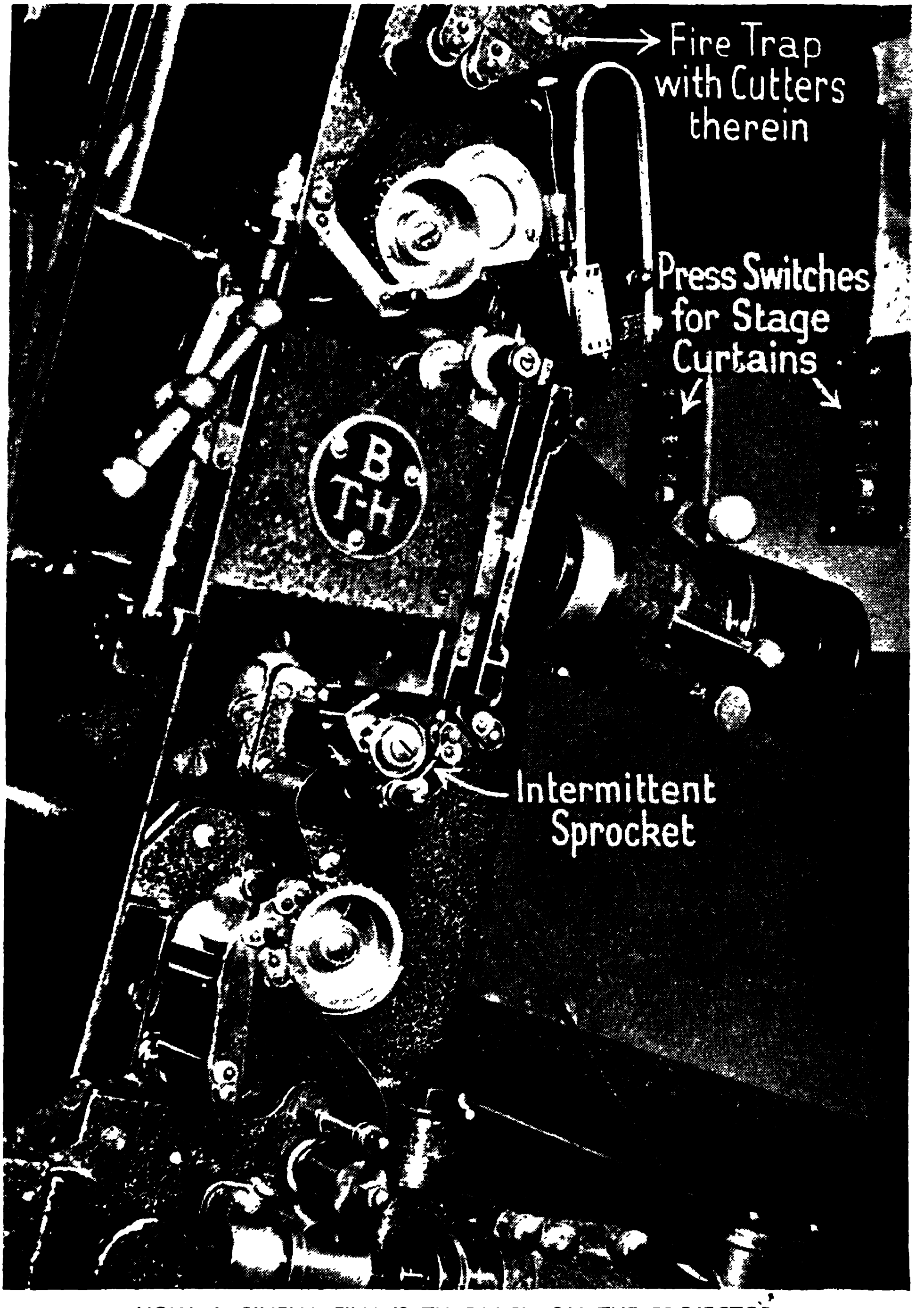
A staircase flight can be further telescoped and combined into a single deep lock as in Fig. 11, C, side ponds again being used to minimize water consumption. The size of the lower gates is kept down by constructing a permanent end wall above the clearance level, transforming the open chamber into a deep shaft with an outlet tunnel at the end.

The canal lock is, for the work it has to do, a comparatively simple and inexpensive device, and under normal conditions performs its functions admirably. No machinery or auxiliary power is necessary, nor constant supervision by skilled labour, and it is very seldom indeed that a serious breakdown occurs. There are conditions, however, for which a lock is unsuitable; perhaps the water consumption is more than can be allowed, or the total rise desired within a limited distance may be greater than can be managed in a flight of locks of reasonable rise. In such cases some form of lift may prove more satisfactory, the principal varieties being shown diagrammatically in Fig. 12. The inclined plane method is no longer employed, the main disadvantage being the risk of straining the boats when hauling them out of the water. The later forms of inclined lift comprise a pair of counterbalanced tanks supported on wheels running on inclined fixed tracks, the motive power being provided by steam, oil, or electricity. Occasionally the need for an external source of power is avoided by arranging for an extra layer of water to be run into the upper tank when ready for movement. The out of balance load created suffices to set the lift in motion.

Many types of lifts have been constructed or suggested in recent years, but in spite of the ingenuity which has been expended on them they have not been popular. The tendency, in Britain at least, is to rely on the essential simplicity and economy of the lock system.



LIFTS—ALTERNATIVE TO LOCKS
Fig. 12. Under certain conditions locks are unsuitable, for example when the water consumption is more than can be allowed. In such cases some form of lift proves more satisfactory. The principal varieties are shown here diagrammatically. Inclined lifts of several varieties now largely replace the inclined plane method



HOW A CINEMA FILM IS THREADED ON THE PROJECTOR

Fig. 1. Before the motor is started the film must be threaded through the projector—a process which is known as lacing up. Though hidden at times the twisting and turning path of the film can be traced in the illustration here given. The rapid movement of the film is imparted by the intermittent sprocket. This toothed wheel makes a rapid quarter turn, stops, then goes on again with an intermittent movement which is continually advancing the film a frame at a time

HOW CINEMA FILMS ARE PROJECTED

Film frame and sound track. Lacing up the film. The projector at work. The carbon arc lamp. The sound gate. Synchronizing picture and sound. Precautions against fire. The change-over cue.

An enlargement of a short length of cinema film is reproduced on p. 254. Let us imagine that it has shrunk to its original width and become a piece of a real film only 35 mm. wide, and let us further imagine that it has been restored to its place in the long length of film from which it was cut. We are examining one of the flimsy strips of celluloid that can be the means of moving large audiences to laughter or to tears, of pleasing the eye and, at the same time of delighting the ear.

Centrally along its length runs a succession of tiny images called "frames," each frame usually differing, but only fractionally so, from the frame just above it and the frame below. It is just perceptible in the strip of film that the head of one of the actors is being turned. At one side of the frames runs the sound track consisting of a black and white photographic image in the form of peaks and valleys in a narrow band.

Near the two edges of the film are small sprocket holes in which moving teeth can momentarily engage to induce it to wind its way, when required, through projectors, two of which are shown in Fig. 3. Let us follow the course of a reel of film through a projector so that by the time it has uncoiled itself from the upper spool and coiled up again on the lower one every stage of its journey may have been analysed, and the subtle piece of witchcraft by means of which pictures appear to move within themselves and mere images to talk, may be robbed of many a mystery.

The film is fed through the projector at a constant speed of twenty-four images or frames per second. As there are sixteen frames per foot of film it follows that exactly $1\frac{1}{2}$ ft. of film per second, or ninety per minute, pass through the projector. It also follows that the frames shown in Fig. 2 would all four serve their purpose in one-sixth of a second. If the length of a film in feet is divided by ninety the showing time is of course given in minutes. Thus 1,000 ft. lasts eleven minutes and about six and a half seconds. For programme purposes times of showing can be accurately planned.

LACING UP THE FILM

Naturally a film must be threaded through the projector—"laced up" is the technical term—before the motor is started. In Fig. 1 the twisting and turning path of the film, though hidden at times, can be traced from top to bottom of the photograph and from Fig. 4 a still clearer and more complete idea of this path may be obtained, though in the diagram a different type of projector is illustrated. From this point in the chapter it will be convenient to refer again frequently to Fig. 4 on various details.

After the film has been laced up all is ready when the time comes to switch on the light source to transmit the fleeting

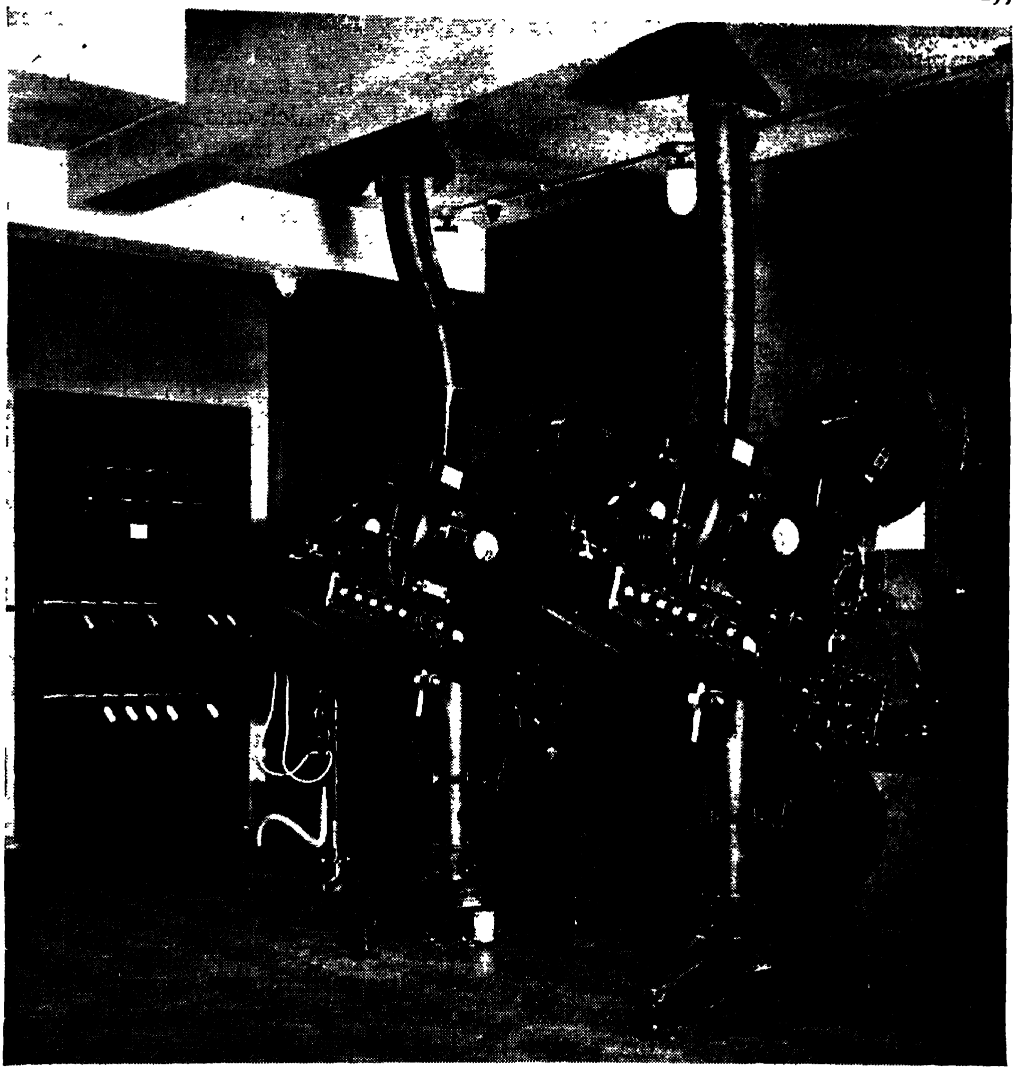
FILM FRAMES AND SOUND TRACK

Fig. 2. The strip of film comprises a succession of tiny images, called frames, each fractionally different from the adjacent images. At the left can be seen the sound track. At the two edges are sprocket holes in which moving teeth engage.

images to the screen, and the sound system to produce the sound, and finally the projector motor to drive the film forward on its journey. First, however, a switch is pressed to draw apart the outer curtain in front of the screen. Then comes a rather tricky piece of timing. As the projector is started, and the image appears on the screen through the transparent inner curtains, another switch is pressed so that these in turn are drawn aside to reveal the picture title quite unobscured. As this is happening a lever is moved to dim the house lights in the auditorium. Another lever or set of levers are also moved to fade out the changing and blending coloured lights used to illuminate the screen curtains and the screen itself to a lesser degree during the preliminary titling of the film. If music was being played on the electric gramophone—known as the non-sync. because its music is not synchronized with the pictures on the screen—this has also to be faded down as the incidental music recorded on the sound track of the film is correspondingly faded in.

Now the projector is purring and the film feeding through gates and past sprockets on its devious course. The spool at the top of the machine, known as the take-off spool revolves on the take-off spindle in the top spool box (see Fig. 4). The first, or take-off sprocket draws the film smoothly from the spool through the fire trap of the spool box. Fire traps and other safety devices will be referred to later in the chapter.

After passing the take-off sprocket, which is in the form of a small rotating drum near each outer circumference of which small teeth are evenly set to engage with the sprocket holes in the film itself, the film forms an alternately expanding and contracting loop as shown in Fig. 4. This loop forms a small elastic reserve of film, very necessary as a kind of inverted buffer, because from this point for a time there is a change from a steady to an intermittent movement of the film, each little frame having, while in front of the mask in line with the axis of the lens, to remain stationary for a small fraction of a second. This occurs at the middle of its journey through the



GENERAL VIEW OF FILM PROJECTORS

Fig. 3. The film is wound through projectors of the kind seen above at a constant speed of twenty-four images or frames per second. As there are sixteen frames per foot of film, ninety feet of film pass through the projector per minute. Thus the times of showing can be accurately estimated. Our view shows at left, a dimmer panel which is used for switching lamps on and off gradually.

gate, which, for clearness is shown open in Fig. 4. It should also be noted that the lens in this diagram is swivelled out of its normal projecting position for greater clarity. With the gate closed it would be moved down to embrace the point at which the beam of light is shown to cross. Incidentally, the beam of light in Fig. 4 is shown behaving exactly as if the lens were in its normal position. The gate is rather like the outsides of a sandwich in which the film represents the filling. Metal grooves that support the film are ground very smooth, so that the film passes effortlessly along.

The very rapid jerky movement of the film is imparted by the intermittent sprocket, which, unlike the other continuous running sprockets, makes a rapid quarter turn, stops, resumes with

a further quarter turn, and so on, each intermittent movement advancing the film through the gate by one frame and placing the next image in front of the mask. It is obviously essential that each "frame" remains stationary in the gate during the fractional period of its projection to avoid producing a blurred image on the screen.

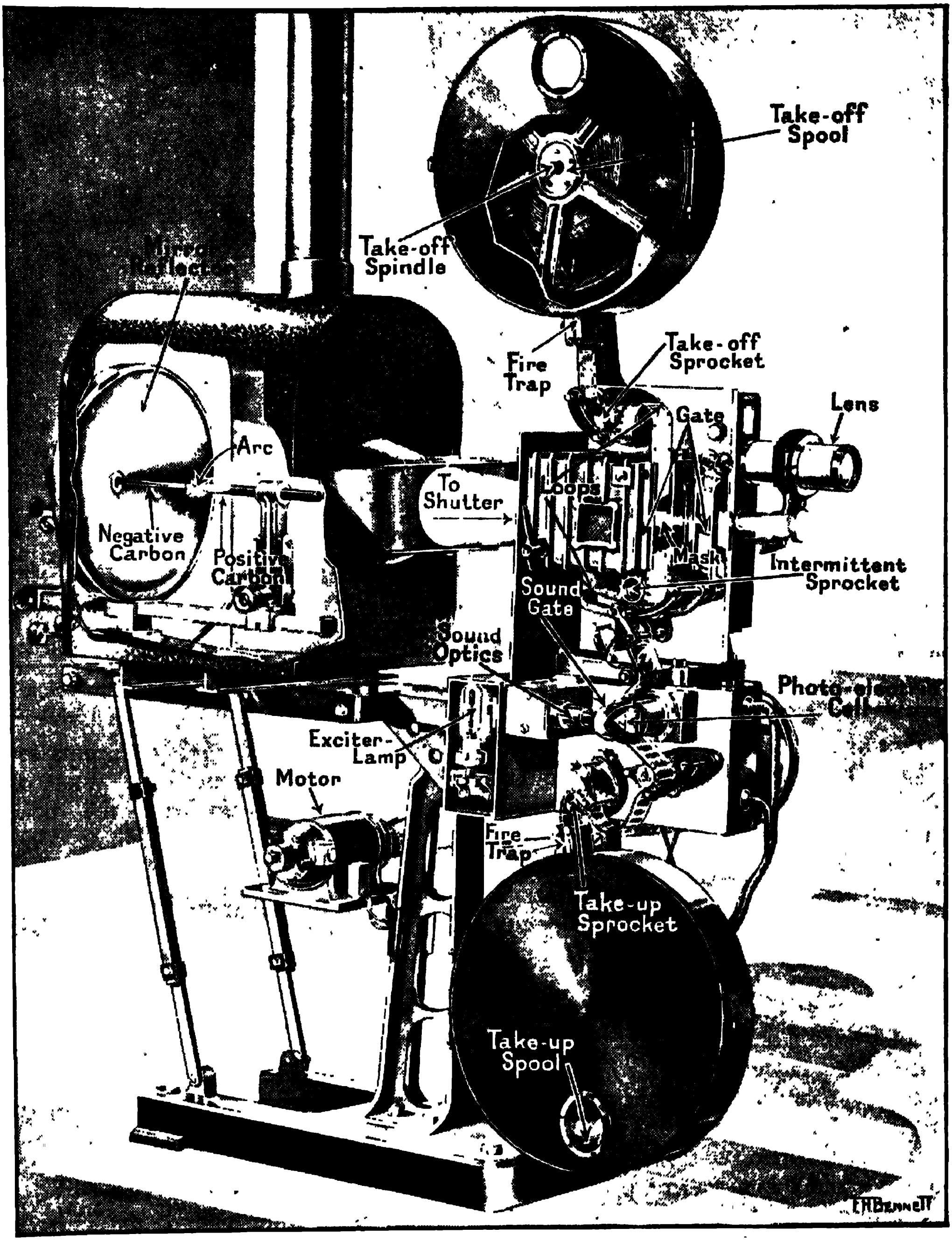
The whole essence of motion picture projection depends upon optical illusion based on the fact that the eye continues to see an image for approximately one-fortieth of a second after the image is removed. As we have seen, the image changes twenty-four times each second, but the actual period when the film is moving forward in the gate to each successive frame is small compared to the time of persistence of sight. The succession of pictures that we see on the screen is so rapid that our brains cannot keep them apart and we receive a sensation of continuous motion. The system adopted to achieve this effect therefore deserves to be analysed fairly closely. Briefly the process is this. Firstly a single frame jumps into position in front of the mask and in line with the lens; secondly rays of light from an arc lamp pass through the film image and thence go through the lens which collects and focuses the light rays on the screen where they are reflected so that a highly magnified image of the small film is revealed. Thirdly, the film image just shown is rapidly replaced by the next succeeding frame, a revolving shutter between the light source and the film cutting off the light, during the change.

The purpose of the revolving shutter blade, which is situated behind the mask on the arc-light side, is, as we have seen, to cut off the light from the film during the split second in which the film is being drawn by the intermittent sprocket through the gate to the next image. Only while the image is momentarily stationary must light pass through it and on through the lens to the screen. The shutter has a second blade called the flicker blade, which cuts off the light for a small part of the time that the image is still. Consequently the light rays passing to the screen are actually interrupted forty-eight times a second, which further heightens the optical effect referred to and removes all possibility of the sensation of "flicker" on the screen.

As has already been noted the light rays cross as they travel through the lens and therefore the film images have to pass through the gate upside down in order to appear the right way up on the screen. The lens must be exactly the right distance from the film or the picture on the screen will appear fuzzy and therefore must be adjusted—focused—to get a clear picture. The lens is clearly shown on the right in Figs. 1 and 5.

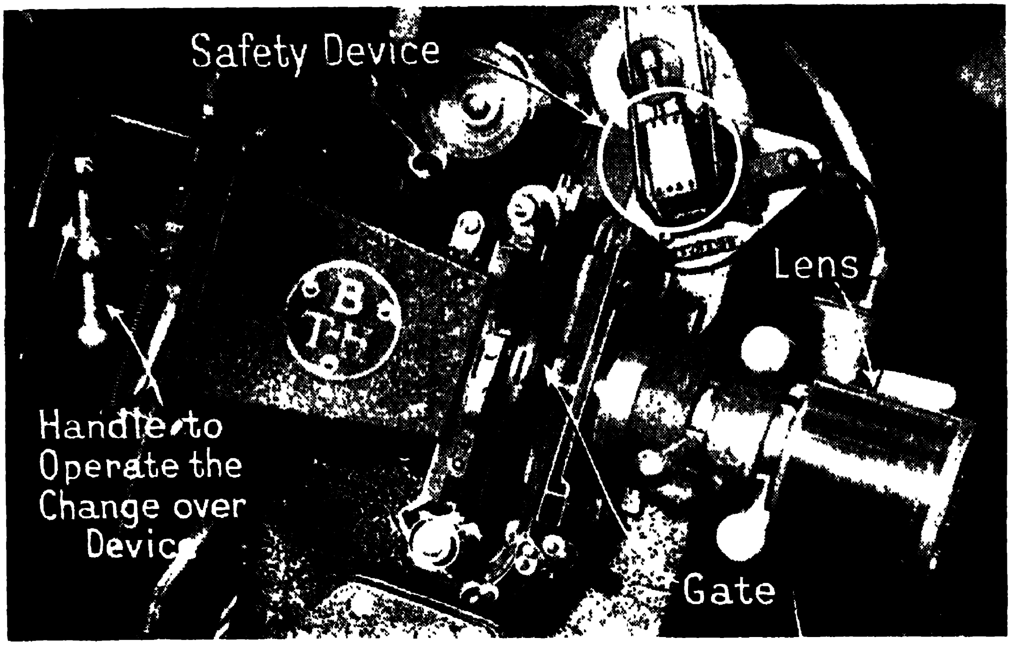
THE SOURCE OF LIGHT

The best source of light for professional picture projection is the carbon arc lamp, the arrangement of which is shown in Fig. 6. Direct current electricity passes between negative and positive carbons causing them to burn slowly but with extreme brilliance centralizing in the crater, or hollow, which forms in the end of the positive carbon. This crater must be at a fixed distance from the concave mirror reflector which focuses an image of the crater on the gate mask so that the light may be most efficiently utilized, and means of adjustment are incorporated to achieve this. On some projectors the arc is viewed through a coloured side window, but on modern machines an image of the actual arc is superimposed optically upon a small diagram outside the lamp house so that the crater can always be accurately placed. A small motor moves the carbons towards the arc at the rate of their burning and needs only occasional adjustment.



DIAGRAMMATIC VIEW OF A FILM PROJECTOR

Fig. 4. From this diagram a complete view of the path taken by a film may be obtained. The take-off spool at the top of the machine revolves on the take-off spindle in the spool box. The take-off sprocket draws the film from the spool through the safety device called the fire trap. The film now forms a loop and passes before the mask, each frame pausing at the gate. Rays of light from an arc lamp pass through the film image and thence through the lens, which focuses the light rays on to the screen. The picture is prevented from flickering by the action of a revolving shutter.



DEVICE FOR CUTTING FILM IN THE EVENT OF FIRE

Fig. 5. Near the upper fire trap is the device shown here. A small piece of celluloid is gripped between two sets of teeth. If the film catches fire, so does the celluloid, the teeth spring apart and knives cut the film in the fire trap, switch off the arc and stop the motor. In this way about a yard of film is isolated, so that this portion only can burn. The subsequent join is almost imperceptible.

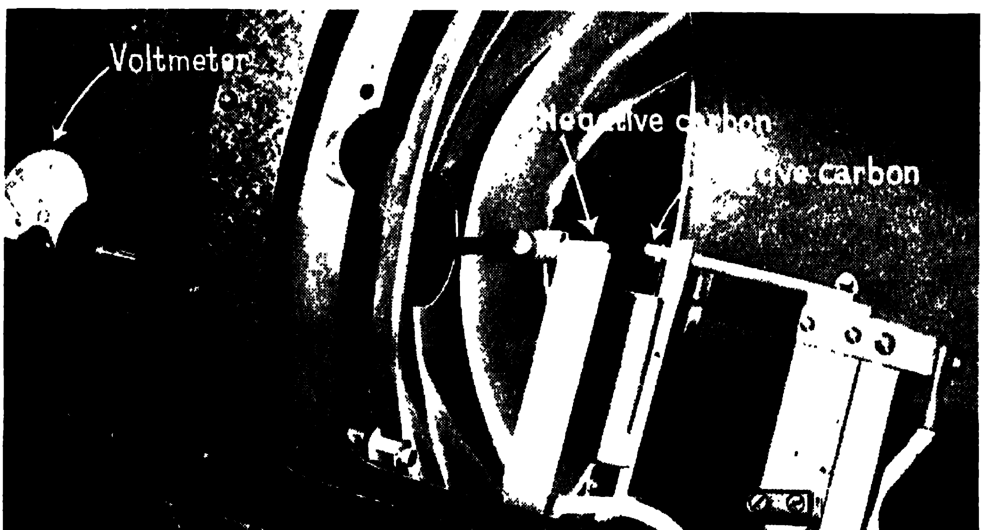
Let us now follow the progress of the film as it leaves the intermittent sprocket. It must once more resume a steady continuous movement. A second loop of film must therefore be left as a buffer before it passes round the next constant speed sprocket in order to avoid any snatch which would tear it. Both top and bottom loops are indicated in Fig. 4 as also is the sound gate to which the film is now being drawn. It is vital to pass the film through the sound head smoothly, and at constant speed, or variation in pitch and tonal quality will result in distortion of the sound. Distortion is avoided in modern apparatus (Fig. 7) by passing the film over a magnetically controlled rotating drum which is perfectly smooth and without sprocket teeth, and so eliminates all possibility of sound distortion due to ripple from the sprocket holes and other causes. The magnetic control of the speed of this drum is obtained by eddy currents set up in a copper armature by a system of field magnets driven from the main gearing of the projector. These eddy currents cause the drum to rotate and also damp out any variation in speed. A small amount of slack must be left between the lower continuous constant speed sprocket of the picture mechanism and the constant speed sprocket following the sound gate in order that the drum can take complete control of the speed of the film within the very fine limits necessary for the reproduction of the sound.

In this sound head there is no sound gate proper similar to the picture gate already discussed. Instead, the smooth film drum which controls the speed so exactly whilst the film is in contact with it, is not quite so wide as the film, and the sound track protrudes over the edge of the drum. At this point, a system of lenses known as the sound optical

system, focuses a thin pencil of light from the exciter lamp on the sound track, and as the film progresses on its way, the succession of peaks and valleys representing vibrations of different sounds, permits varying amounts of light to shine on the sensitive photo-electric cell. This cell has the property of transforming light variations which fall upon it into electric impulses, and these, stepped up by the amplifier, cause the loudspeakers behind the screen to reproduce the actual sound vibrations which make the words and music audible.

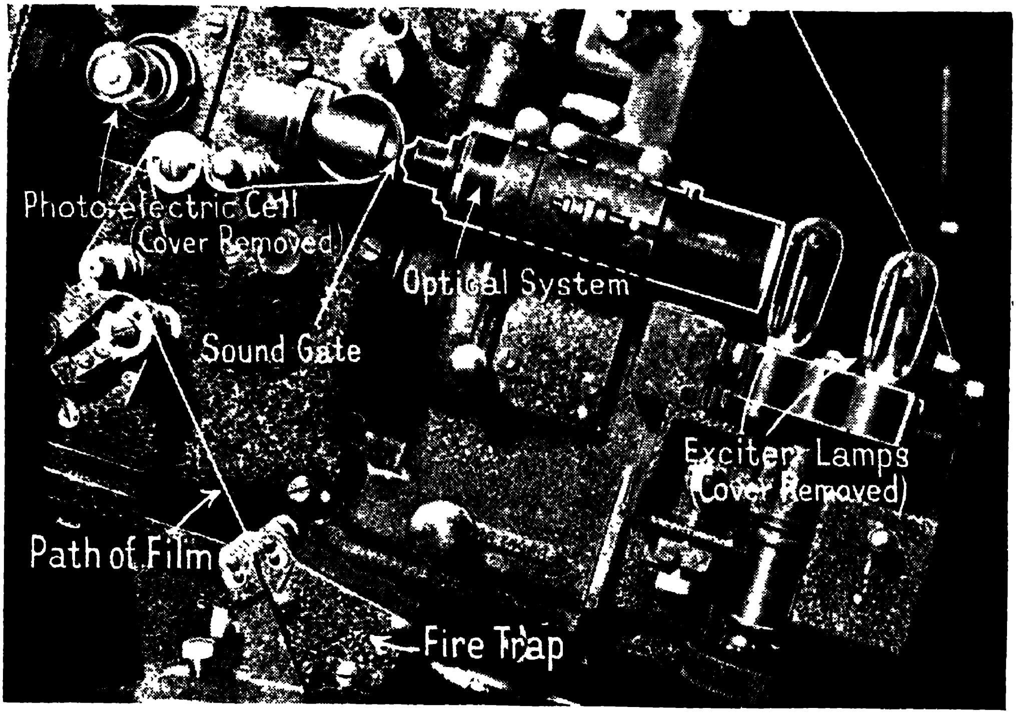
It will be seen that as the sound gate receives the film later than the picture gate, the sound track must be well in advance of the film image, so that sound and vision coincide, as far as the bulk of a cinema audience is concerned. Actually those in the front seats of very large theatres hear the sound fractionally sooner than those in the back, though they see the action of the picture simultaneously, and it has been found that perfect synchronization over the whole auditorium is not scientifically possible.

Because fire is a great danger with inflammable celluloid film, great precautions are taken to insure against it. The take-off spool is housed in a container or spool box whose safety catch automatically cuts out the arc-light if an attempt is made to open the door while the film is running. Two additional safety measures are incorporated in modern projectors. The first is provided by the fire traps already referred to, and shown in Fig. 4. These are fitted to the top and bottom spool boxes and enclose the film tightly to prevent fire spreading up to the take-off spool, or down to the take-up spool. The second, which is near the upper fire trap is a device for cutting the film in the event of fire (Fig. 5). A small piece of celluloid has sprocket holes on both sides in tension between two sets of small teeth. If the film catches fire, so does this piece of celluloid, the two sets of teeth spring apart, an electrical connection is made, and knives cut the film in the fire trap just below the take-off spool and just above the take-up spool, switch off the arc and stop the projector



HOW LIGHT IS PROVIDED FOR FILM PROJECTION

Fig. 6. The carbon arc lamp is the source of light. Direct current electricity passes between the negative and positive carbons causing them to burn slowly but with great brilliance. The mirror reflector focuses the image on the gate mask. A motor moves the carbons towards the arc.



HOW SOUND AND VISION COINCIDE

Fig. 7. A system of lenses known as the sound optical system focuses a thin pencil of light from the exciter lamp on the sound track and as the film proceeds on its way the peaks and valleys representing vibrations of sound permit varying amounts of light to shine on the photo-electric cell. This transforms the vibrations into electrical impulses which are stepped up by an amplifier.

motor. In this way about a yard of film is isolated, so only this portion can burn, and moreover so little is wasted that the subsequent join is almost imperceptible. A question remains: how is the projection of one reel on one projector faded into that of the next reel on another projector, without flicker on the screen or discontinuity in the sound?

The second projector is standing by, with its film all ready laced up so that the sound track is in position to synchronize with the end of the film on the first projector. Identifying marks on the early part of the film make it possible for the operator to position his film exactly.

As the first film nears the end, 13½ ft. from its finish there are four frames containing a black dot which appears at the top right-hand corner of the screen. The audience does not see these dots as only the trained eye can detect them. They are the motor cue for the change over, and when they appear the motor of the second projector is started. About 10 ft. later, when the second projector is up to speed, again four frames appear.

At the signal on screen or reel the operator on the second projector simultaneously cuts in the light on his machine, and cuts off the light on the first projector the controls being interconnected by means of a Bowden cable. At the same time the operator switches in his sound, which likewise automatically cuts off sound on the other machine. Part of the mechanism by which this is achieved is shown in Fig. 5.

All this is done with great smoothness, so that the audience is quite unaware of the change and is able to enjoy what it sees and hears without distraction.

HOW FIRE EXTINGUISHERS AND SPRINKLERS WORK

Portable extinguishers. The soda-acid type. The foam type. The foam hand pump. The methyl-bromide type. The carbon-dioxide type. The pistol extinguisher. Sprinkler systems. The multiple-jet system. Extinguishing oil fires. Drencher installations.

FIRE is capable of destroying goods at the rate of a great many tons a minute. This fact sufficiently demonstrates the need for first-aid fire appliances enabling quick action to be taken. These include: buckets filled with water, sand, or inert dust; soda-water syphons; hand pumps; portable, semi-automatic extinguishers and automatic, or manually-operated, fixed installations.

Probably the extinguisher best known to the general public is the 2-gal. soda-acid machine seen in places of public entertainment (Fig. 1). In the majority of instances, its cylinder contains bicarbonate of soda in solution in water, and, in a special bottle, a charge of pure sulphuric acid. By inverting the cylinder, or by driving in a piston at the top of it, or by hitting the cylinder smartly on the side with a hammer attached to the appliance, the sulphuric acid is discharged into the alkaline solution, and carbon-dioxide gas generated. This gas, reaching a maximum pressure of 190 lb. to the sq. in., is the propellent of the fluid. The approximate time of discharge is 60 seconds, and the effective range, horizontally, is about 36 ft. to 40 ft. Instead of the sulphuric acid and bicarbonate of soda, clean water, with carbon-dioxide, in cartridge form, can be used; or, in buildings with abnormally low temperatures, calcium-chloride in a solution of water is satisfactory.

Any of these extinguishers is suitable for use on freely-burning fires, affecting ordinary combustible commodities where the quenching and cooling effect of quantities of water are of first importance. With a spray-and-jet nozzle, similar to that of the stirrup pump, they can be used with effect on the "kilo" type of incendiary bomb. One 2-gal. extinguisher is deemed sufficient protection for 2,500 feet of floor space; but the user must be competent.

FOAM EXTINGUISHERS

Another class is formed by the foam, or "suds," extinguisher, which is eminently suitable for dealing with burning fats, oils, and volatile spirits, such as petrol (Fig. 2). The most common capacity is the 2-gal., which, in operation, at ordinary household temperatures, will produce 17 gals. to 20 gals. of foam, a viscous compound, the action of which is to suffocate fire by excluding oxygen.

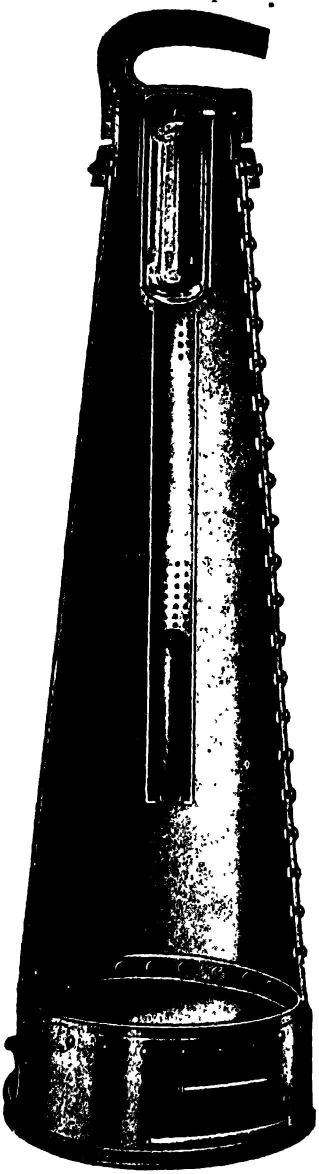
The ingredients that produce this effect are: bicarbonate of soda; a stabilizing agent, both dissolved in water; and, within an inner, and smaller, cylinder, aluminium-sulphate dissolved in water. Reaction, when this inner cylinder is opened from without, produces carbon-dioxide gas, in the form of bubbles in which a light precipitate of aluminium-hydroxide is incorporated. The stabilizing agent strengthens their structure.

Foam should be always applied gently upon the inside walls round the fire, so that it spreads over every surface in range, kills the fire and prevents re-ignition. Time of discharge and effective range of a 2-gal. foam extinguisher are the same as those of a 2-gal. soda-acid machine.

There is a portable foam hand pump, the output of which is limited only by the quantity of water and saponin extract necessary to keep it in action. Such appliances are popular on the Continent, and some are carried by fire engines in this country.

The next type of portable, liquid, extinguisher provides a vapour that stifles combustion of electrical apparatus, oils, spirits, and, even, general fires. The vapour is caused by the contents of the extinguisher, carbon-tetrachloride (CCl_4) striking the fire. The chemical reaction is a heavy, inert, gas. This type of extinguisher is popular with motorists, and takes the form of a pump gun holding a quart, or two quarts, of carbon-tetrachloride. The stream from the extinguisher should be directed at the base of the flames, or, if the burning material is in a receptacle, it should be applied in the manner prescribed for the application of foam.

A very small percentage of the vapour, in contact with gases generated by the material on fire, produces hydrochloric acid, which, with its biting, intolerable smell, compels all exposed to it to seek fresh air. This irritant quality is a valuable factor as it warns the operator of his danger, because, in small, confined spaces, especially when the material on fire is giving off dense smoke and showing little, or no, flame, phosgene is present. Being a solvent, carbon-tetrachloride has a deleterious effect on rubber, but does not injure other commodities.



SODA-ACID EXTINGUISHER
Fig. 1. This extinguisher, reproduced by courtesy of Merryweather and Sons, Ltd., operates by the action of sulphuric acid on an alkali generating carbon-dioxide which propels the liquid.

Methyl-bromide is another vapourizing, fire-extinguishing medium. It is a liquid with a very low boiling point and, therefore, refrigerative in action. It is non-corrosive, non-conductive of electricity and of considerable value in extinguishing fires in celluloid (which feeds on its own oxygen), oils and spirits. The liquid is carried in cylinders, capable of withstanding the pressure exerted by the discharge of a carbon-dioxide cartridge carried inside the cylinder (Fig. 4) Every R.A.F. aircraft is protected by a fixed installation which, on operation, will discharge methyl-bromide.

Another inert gas used in fire fighting is carbon-dioxide, liquefied at about 600 lb. to the sq. in.

At normal temperature and atmospheric pressure, this gas is $1\frac{1}{2}$ times heavier than air, and a non-supporter of combustion. It is carried in a cylinder, the capacity of which should be at least 7 lb. of the liquid, and is discharged through a special, conical-shaped horn (Fig. 3) at a temperature of minus 110 degrees Fahrenheit! Effective range is short and, using a gas, this class of extinguisher is best suited to enclosed fires. The gas has no deleterious effect on commodities.

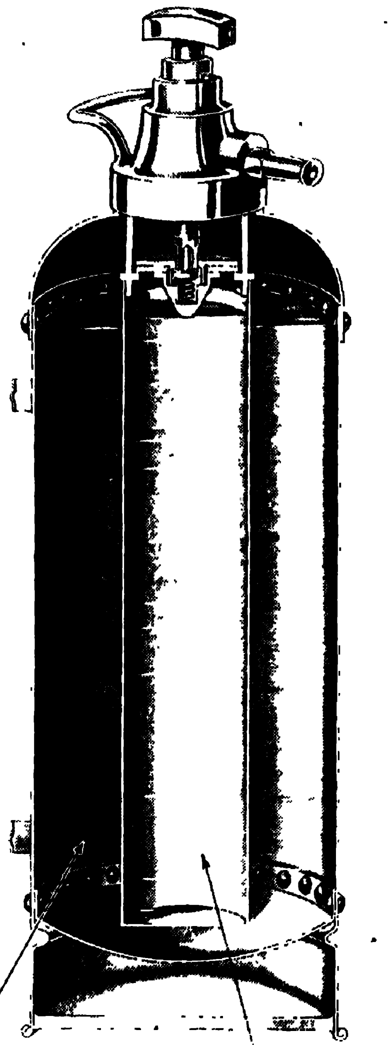
There are also first-aid extinguishers in pistol or cylinder form, which discharge dry, chemical compounds in which bicarbonate of soda plays a prominent part. The propellent is CO_2. This type of appliance is suitable for the extinction of inflammable liquids in vats and pools and electrical apparatus. It is also of value for the protection of *objets d'art* on which water and other liquids would have damaging effect. As in the case of the CO_2 extinguisher, the cartridge should be weighed, annually, for the detection of leakage.

SPRINKLER INSTALLATIONS

The sprinkler system attacks a fire at its place of origin, and in its early stages.

Heat generated by the fire automatically brings the equipment into operation and at the same time causes notification to be given of the outbreak Before a fire has time to get out of hand, sprinkler heads in the immediate vicinity open and allow a shower of water to fall on the fire.

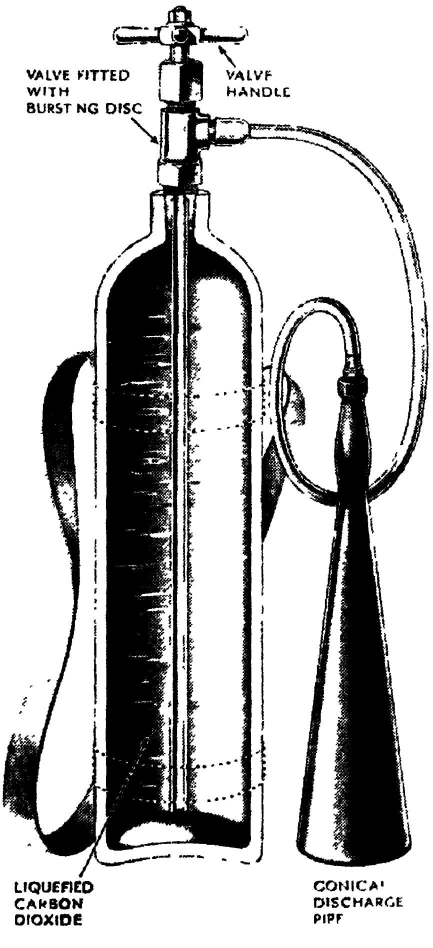
The arrangement of the main and subsidiary pipes of a sprinkler installation resembles a tree. The main pipe, bringing water to the sprinklers, is carried through the central parts of the structure and from it, in all directions, runs metal piping. This constitutes the branches, while the buds are the sprinkler heads. Each head or "rosette" has a valve, held in position by a lever or strut, which falls away and allows the valve to open immediately the temperature rises above a predetermined level. The temperature at which a sprinkler head operates varies according to the character of the room where the equipment is installed, 155 degrees Fahrenheit being the operating temperature selected for most



FOAM EXTINGUISHER

Fig. 2. Bubbles of gas generated by the contents of this extinguisher form a foam which spreads over the fire, suffocating it by excluding oxygen.

buildings. For many years the strut itself was composed of three pieces of metal united by means of a special type of solder designed to fuse at a predetermined temperature. When the fusible solder is softened by heat of a fire the strut falls apart and the glass valve is thrown away by pressure of the diaphragm. This soldered strut type of head proved quite efficient, but in a device such as a sprinkler installation which may come into operation only after lying dormant for many years, it is essential to guard



CARBON-DIOXIDE EXTINGUISHER

Fig. 3. Carbon-dioxide, an inert gas, is carried in a cylinder containing at least 7 lb. of liquid and is discharged at low temperature through a special conical-shaped horn. It is most effective if it is used on enclosed fires at close range.

against the risk of corrosion. In modern sprinkler installations, therefore, the soldered strut has been replaced by a sealed quartzoid bulb which contains a highly expansible liquid in which a bubble of gas is entrapped. When the head is exposed to a rising temperature the liquid expands and the bubble decreases until a point is reached at which the bubble finally disappears and the bulb is entirely filled with the expanding liquid. A further increase of temperature causes the pressure within the bulb to rise until it becomes irresistible.

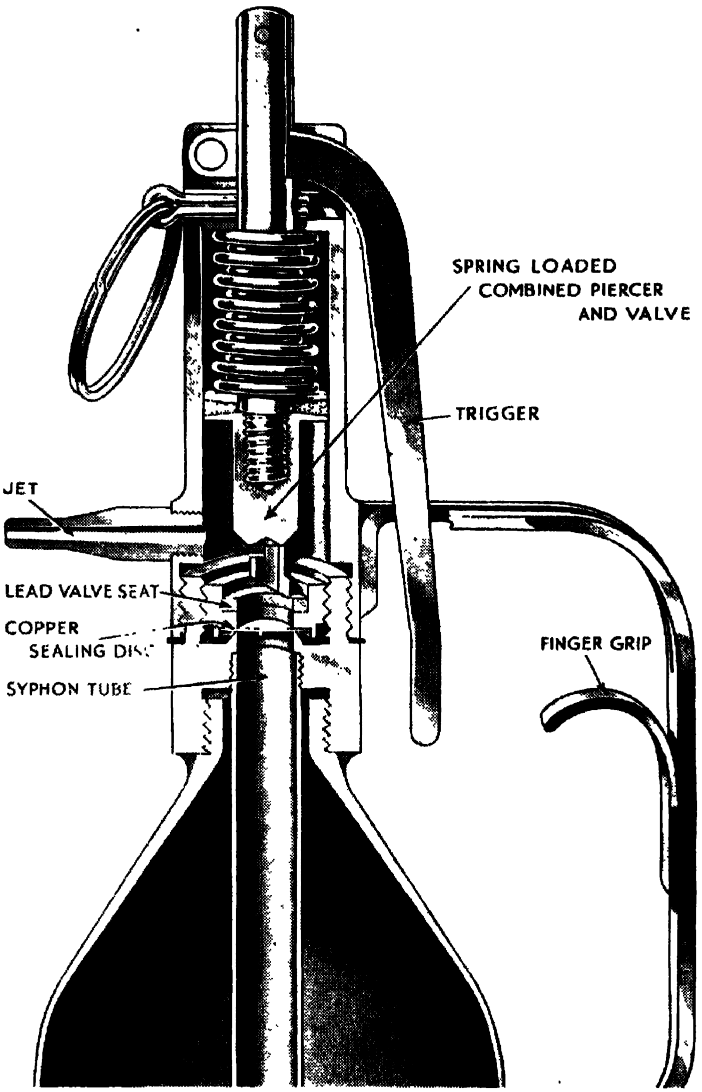
A jet impinges on a deflector with the result that the water, in shower form, strikes on the ceiling and falls to the floor or on objects in the vicinity of the fire. Simultaneously, the water passing through the pipes to the open head or heads actuates an alarm gong.

Sprinklers are usually 10 ft. apart and 5 ft. from walls, but in circumstances where the fire risk is high, they may be placed at intervals of 8 ft. and within 4 ft. of the walls.

It is, of course, essential to have a good water supply, with an alternative supply to be on the safe side. There are fire risks where three independent sources of water supply are necessary to ensure adequate protection. One source of supply should be capable of delivering water at high pressure throughout the system. This can be provided by a gravity tank from 25 ft. to 50 ft. above the topmost sprinkler head, or by an air-pressure tank, filled partly with water and partly with air under sufficient pressure to deliver the last drop of water in the tank to the highest sprinkler in the protected building. The domestic water supply service may also be used. Some public supply systems provide water at adequate pressure for sprinkler purposes, but where the standard pressure is too low it can be brought up to sprinkler requirements by means of a

booster pump. An alternative supply may be provided by a power pump that can be automatically started by a fall in the water pressure within the system.

Each sprinkler head discharges about 20 gals. of water a minute, and water to the brim of a 10,000-gal. tank would keep fifty heads in action for ten minutes, following which a secondary source of supply would be needed. Statistics covering thousands of fires prove that an outbreak seldom brings as many as fifty sprinklers into action. In normal times most fires are extinguished before many sprinklers open and six heads per fire could be taken as a fair average.

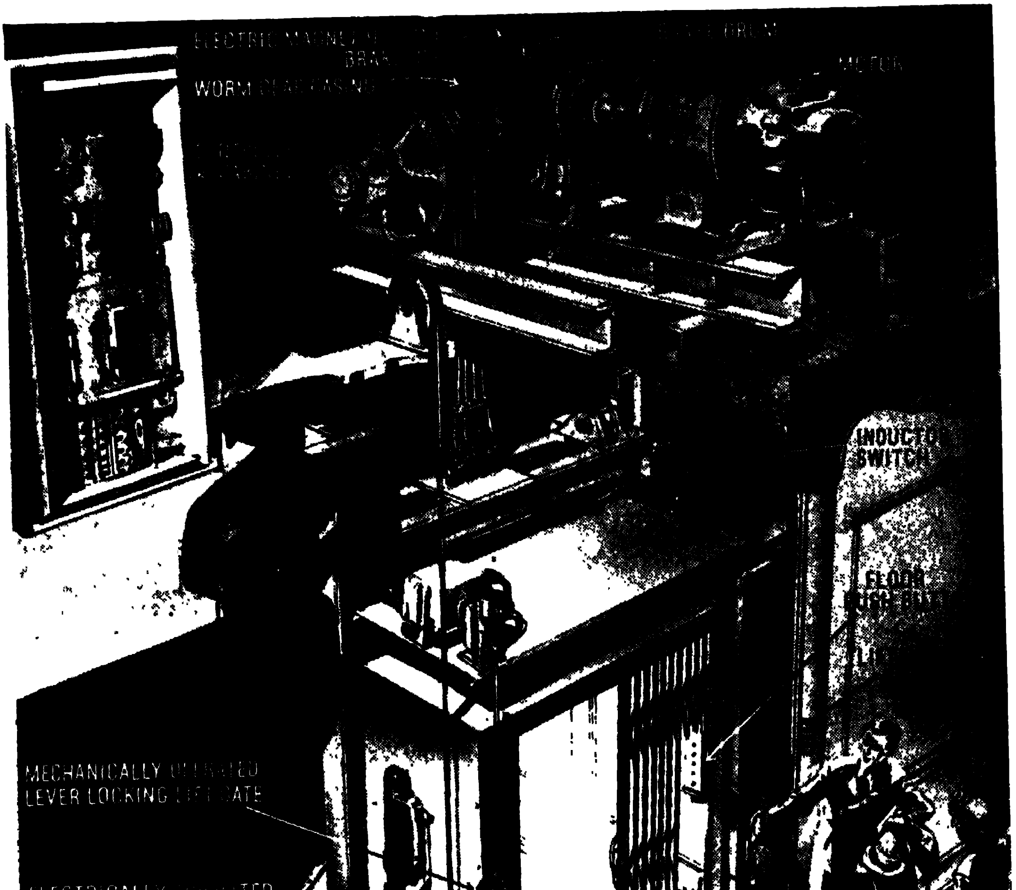


HEAD OF METHYL-BROMIDE EXTINGUISHER IN SECTION

Fig. 4. This appliance is operated by piercing the copper disc sealing the syphon tube, whereupon carbon-dioxide mixes with methyl-bromide contained in the cylinder. The liquid, of low boiling point, is refrigerative in action. This type of extinguisher is installed in all R.A.F. aircraft

The danger of water freezing in the pipes is now overcome by charging the installation pipes with air at moderate pressure and holding the water back beyond the reach of frost by means of a differential air valve. When sprinkler heads are opened by the heat of fire the air quickly escapes and a fall in pressure causes the differential valve to open. This releases the water, which is allowed to enter the sprinkler pipes.

The advantages of the wet-pipe system—with water always present in the pipes—is that immediately the sprinkler heads open a shower begins. In the dry-pipe system a certain amount of time is lost before the sprinkler can play on the fire, because the air must be discharged from the pipes before the water can reach the open heads



INGENIOUS HIDDEN MECHANISM OPERATES THE AUTOMATIC PASSENGER LIFT

Merely by pressing a button, the passenger sets in motion the wonderful unseen machinery of an automatic lift, rendered foolproof to accidents by an instantaneous safety gear and electrically operated gate locks. The machinery is here exposed diagrammatically,s howing principal parts.

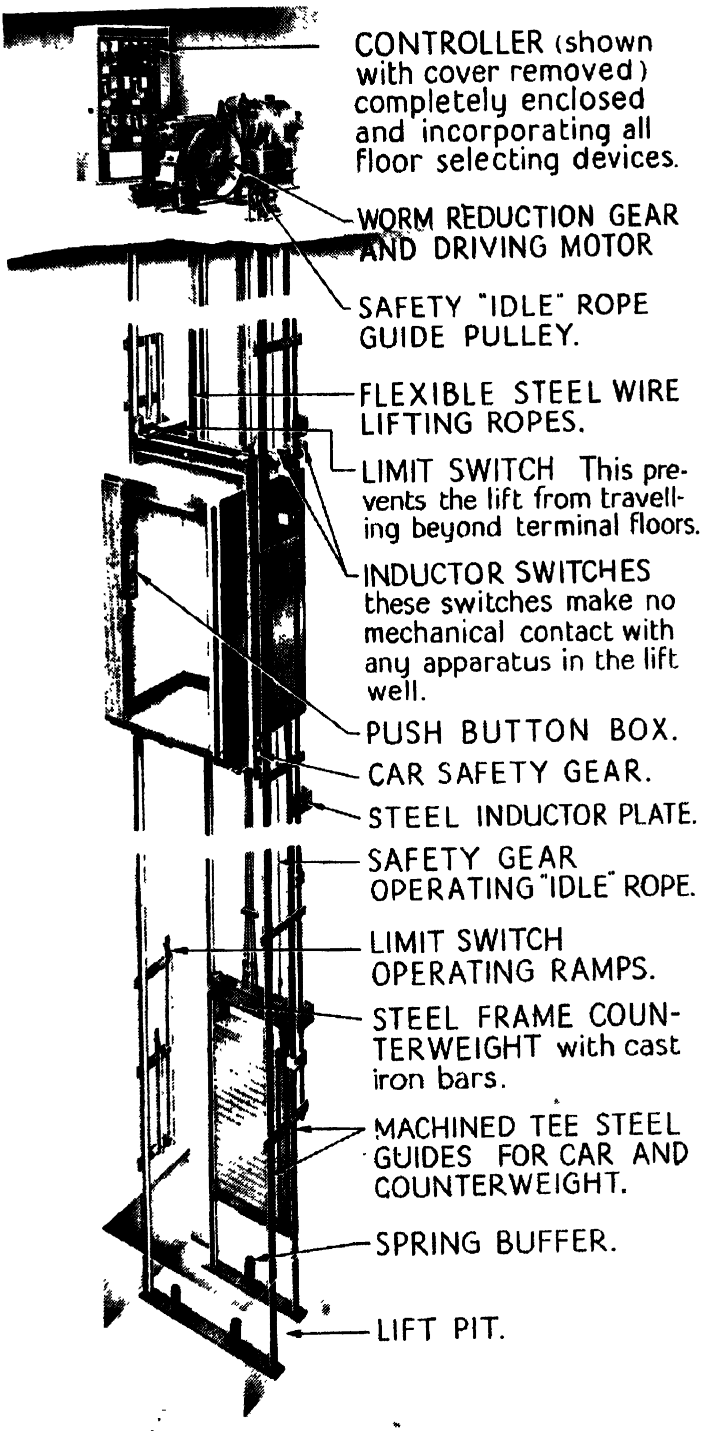
WHAT HAPPENS WHEN YOU USE A LIFT

The safety gear. The counterweight. Driving mechanism. Brakes. The controller. The signalling system. Lift speeds. The electric eye.

NOWADAYS there are many different types of electrically operated lifts and of these perhaps the most ingenious is the fully automatic type which is operated by the passenger himself by means of push-buttons and requires no attendant. Naturally such lifts have to be as near foolproof as possible otherwise serious accidents would be liable to occur through ignorance or carelessness on the part of the user. So let us take a look at this wonderful piece of mechanism and see how it obeys the wishes of its user by the mere pressing of a button inside the car or on a landing. The elaborate assembly of parts which goes to make up the complete lift equipment may be broadly divided into two classes: (1) those that are wholly or mainly mechanical and (2) those that are wholly or mainly electrical. In the former category are included the lift entrances, the car, the counterweight, and the winding gear. The electrical equipment comprises the driving motor, the controller, switches, push-buttons and locks.

Fig. 1 shows, by courtesy of Express Lift Co., the general layout of a modern fully automatic push-button electric lift. The winding gear and controller are situated at the top of the building over the lift. This is the usual arrangement, but sometimes machinery is installed below or at the side of the lift. The passenger-car is guided throughout the length of its travel by polished steel guides which are rigidly fixed to the building. Formerly, guides of circular section were used for all but high-speed lifts, but the modern tendency is to use T-shaped guides for all lifts irrespective of speed. The passenger-car itself has polished guide shoes of gun-metal or cast iron fitted to its sides which engage with the guides, hold the car steady and ensure smooth running during its journey from one floor to another.

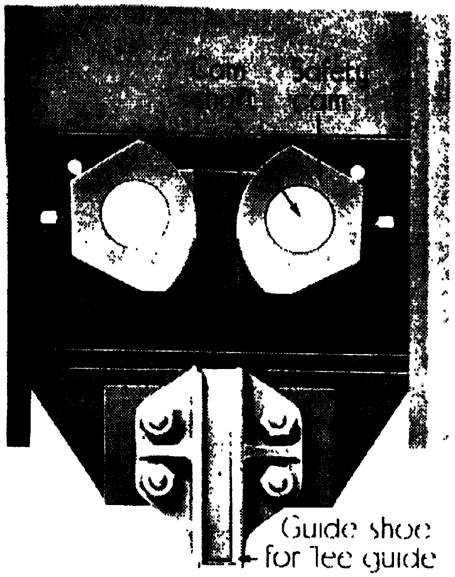
Underneath the car a safety gear is fitted usually consisting, in the case of lifts of moderate speed, of four eccentric cams disposed in pairs on each side of the car, as may be seen in Fig 2, and on either side of the lift guides. Each cam is made of hardened steel and has fine pitched teeth cut in its face. Normally the cams are just clear of the lift guides. The cams are fitted to two shafts which extend across the bottom of the lift car and are so linked together that if any one cam is rotated all four cams turn in unison. In the simplest form an "idle" rope (Fig. 1) is fastened to one of the cams and is led up to the top of the lift shaft, over pulleys and down to the counterweight where it is securely anchored. In the somewhat remote possibility of the lifting-ropes breaking, the falling counterweight tightens the idle rope, which rotates the cam to which it is attached, whereupon all four cams turn in unison until their toothed surfaces come into contact with the guides and, by a wedging action, maintain the car securely suspended. The profile of the



LAYOUT OF AN AUTOMATIC LIFT

Fig. 1. This diagram shows the main features of a push-button electric lift, the machinery of which is usually situated at the top of the building.

cams is such that the greater the load the more firmly is the car wedged in position. Sometimes the idle rope is replaced by an endless rope secured to the car by an attachment and driving the pulley of an overspeed governor (Fig. 3). In this case the safety gear comes into action should the car commence to descend at an excessive speed for whatever reason. The instantaneous safety gear is unsuitable for high-speed lifts, which are fitted with a safety gear of the type shown in Fig. 4 which, when operated by the overspeed governor (which is invariably used for such safety gears) exerts an ever increasing pincers-like pressure on the guides which brings the car gradually to rest without shock. The gripping levers may be seen in Fig. 5. The car is suspended by a number of highly flexible ropes made of steel wire. Usually not fewer than four ropes are used which in the aggregate are capable of sustaining from ten to twenty times the load they



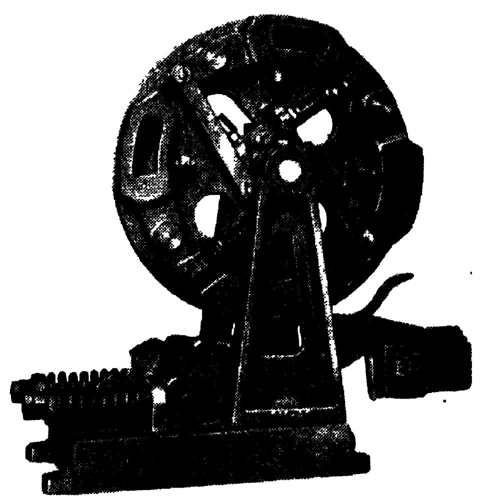
HOW SAFETY GEAR IS FITTED

Fig. 2. Underneath the lift car is the safety gear. Four cams are disposed in pairs on either side of the lift guides as shown here. Should the lifting ropes break, the idle rope is tightened by the falling counterweight, the cams rotate, their toothed surfaces touch the guides, and the car is securely suspended by a wedging action.

are actually called upon to bear. These ropes pass over the driving wheel as you can see in Fig. 1 and attach to the counterweight.

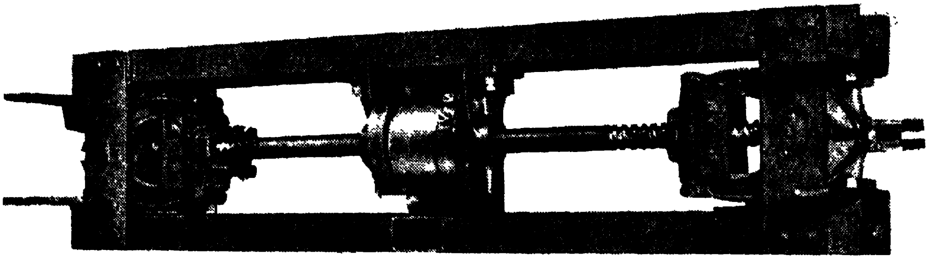
The counterweight is made up of a number of cast-iron bars which fit into a frame (Fig. 6). This frame, like the passenger-car, slides up and down on polished steel guides. The object of the counterweight is to reduce to a minimum the power required to move the car, and its weight is equal to that of the empty car plus a proportion—frequently 50 per cent—of the load the lift is rated to carry. Perhaps an example will make this clear. Let us assume that the weight of the empty car is 2,000 lb. and that it is designed to carry a load of 1,000 lb. balanced 50 per cent. The counterweight will weigh 2,000 lb. plus 500 lb., that is 2,500 lb., and will overbalance the empty car by 500 lb. As a result of this it will follow that although the lift is constructed to take loads up to 1,000 lb. the motor at no time has to deal with a load exceeding 500 lb.

The driving mechanism consists of a worm reduction gearing coupled to the driving motor. Fig. 7 shows the cover removed to show the gearing itself. An electro-mechanical brake is fitted to the unit in order to stop the motor and sustain the loaded car in any position. The drum upon which the brake acts forms also a coupling for connecting the motor shaft to the worm shaft. The brake is applied mechanically by springs, but is released electrically by a powerful electric magnet which is housed in an extension of one of the brake shoes as shown in Fig. 8. In the event of a failure of the electric supply, therefore, the brake is applied automatically. The driving wheel has a number of V-shaped grooves machined in its rim, over which the lifting ropes pass, the wedging action of the ropes in the Vs providing sufficient friction enabling the wheel to drive the ropes



HOW A CAR IS SLOWED DOWN

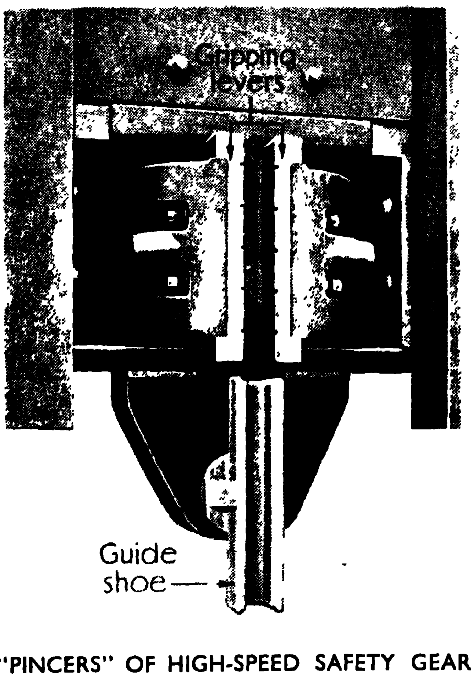
Fig. 3. Sometimes the idle rope is replaced by an endless rope attached to the car and driving the pulley of an overspeed governor, as illustrated here. The safety gear in this case comes into action if the lift begins to descend at excessive speed, which it checks by degrees



SAFETY GEAR OF THE HIGH-SPEED LIFT

Fig. 4. The instantaneous safety gear is unsuitable for high-speed lifts which are fitted with this device. When operated by the overspeed governor an increasing pincers-like pressure causes the gripping levers to bear on the guides, bringing the car gradually to rest without sudden shock.

The openings on the landings may be protected by sliding doors, by hinged doors, or by collapsible steel lattice gates. Whatever type is adopted electrical and mechanical locks will be fitted. Most locking mechanisms include a lever with a rubber-tyred roller at its extremity which projects into the lift well. A wooden ramp with long bevelled approaches is fixed to the lift car and as the latter approaches a floor the ramp engages the lock roller and gently pushes the lever to one side. This movement of the lever releases the locking mechanism and allows the landing doors or gate to be opened. A type of lock used for collapsible steel lattice gates is shown in Fig. 9. The act of opening interrupts the electric lock circuit so that current cannot be applied to the motor while the door or gate remains open. Sometimes the fixed lock ramp is replaced by one operated by an electric magnet fitted on top of the lift car (Fig. 10). Such a device is known as a retiring ramp and is so arranged that while the car is travelling the electric magnet is energized and keeps the ramp from making contact with the lock rollers. When the car stops at a floor the magnet is de-energized thus releasing the ramp which pushes the lock lever aside and releases the mechanism.



"PINCERS" OF HIGH-SPEED SAFETY GEAR

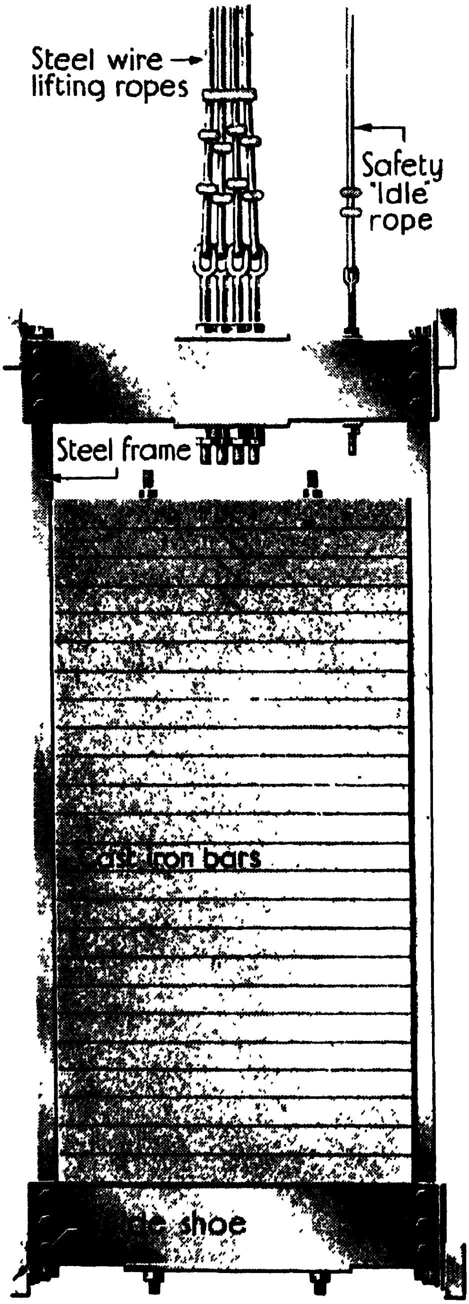
Fig. 5. The levers which exert a steady pressure on the guides are shown in this illustration. Their pincers-like grip slows down the car.

BRAIN OF THE LIFT

Let us now turn to the controller, that wonderful piece of electrical apparatus which constitutes the brain of the lift. A typical fully automatic push-button controller for a single-speed lift is shown in Fig. 12. Actually the controller may be installed anywhere and indeed in some cases, where space in the vicinity of the winding machine is very restricted it is installed in a position remote from the lift. Nevertheless, it is desirable to have the controller near the winding

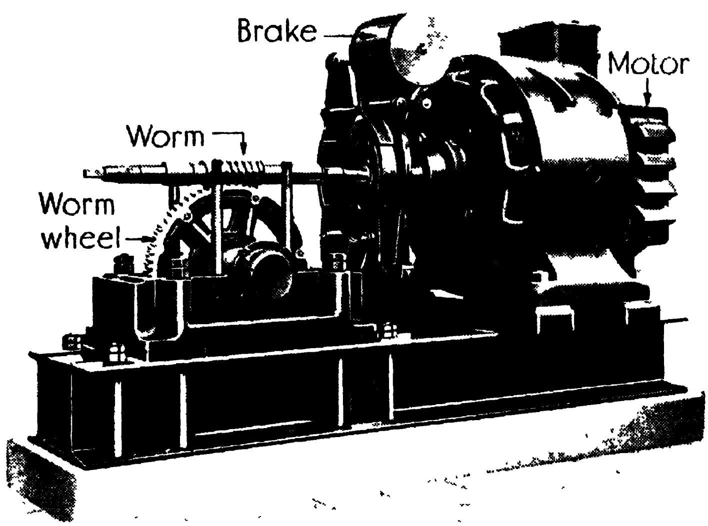
machine, both in order to avoid unnecessary electric wiring and to enable the operation of the motor to be observed when a maintenance engineer is working on the controller. It is usual therefore to fix the latter near the winding machine as may be seen in Fig. 1.

In describing the control equipment the use of technical terms will be avoided as far as possible, but the apparatus is so highly specialized that some use of technicalities must be made, particularly where there are no ordinary language equivalents of the names of components. One function of the controller is to select the floor at which the car is required to stop and several methods of floor selection are in use. That chosen for description here is of comparatively recent introduction and is based on the use of magnetic inductor switches. These are mounted on top of the car. A great advantage of these switches is that they make no mechanical contact with any apparatus in the lift shaft and are consequently very quiet in operation. The controller is an assembly of a number of automatic switches, most of which are referred to as relays or contactors. The controller determines the direction of rotation of the lift motor, starts it in response to pressure on the push-buttons and stops it so as to bring the car to rest at the required floor. Two main contactors—the "reversers"—control the main motor current and the electro-mechanical brake. A single relay is associated with each floor served by the lift and these floor relays "inform" the controller which floor button has been pressed. A multi-contact stepping selector switch is incorporated which moves one step as the car passes each floor and thus informs the controller where the car is situated at a given moment. These contactors and relays are shown in Fig. 12. The floor relays and selector switch in conjunction determine the direction



HOW DRIVING POWER IS REDUCED TO A MINIMUM

Fig. 6. The object of the counterweight, here shown, is to minimize the power required to move the car. It is made up of cast iron bars, fitted into a frame which slides up and down the steel guides. Its weight equals that of the empty car plus a proportion of the estimated load.



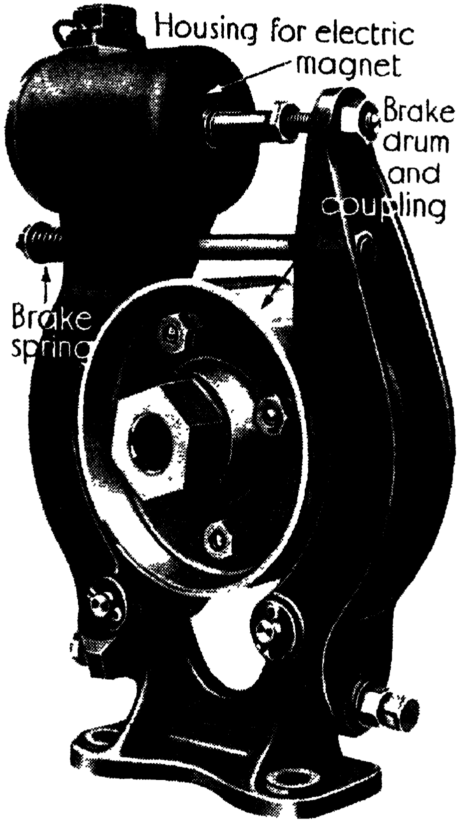
DRIVING MECHANISM OF THE LIFT

Fig. 7. This illustration shows the driving mechanism with the cover removed to expose the gearing. The brake stops the motor and suspends the car. The brake drum connects the motor shaft to the worm gear.

in which the car must travel in order to answer a call. Thus, for example, if the selector switch shows that the car is at the fourth floor and a floor relay indicates that the calling button at the ground floor has been pressed, the car must be started in the downward direction.

Two inductor switches fitted on top of the car operate in conjunction with a number of steel inductor plates disposed in the lift well in each floor zone (Fig. 11). The passage of an inductor switch past an inductor plate interrupts a magnetic circuit in the switch and completes an electrical circuit. In one of the inductor switches each impulse thus created causes the stepping selector switch to move one step. The other inductor switch is concerned with the stopping circuit as will be described below.

Let us suppose that a passenger approaches the lift at ground-floor level, the car being stationary at fourth-floor level. He presses, momentarily, the call button adjacent to the lift entrance and awaits the advent of the lift. Sometimes indicating devices are provided in order to assure the passenger that his call has been registered and is receiving attention. Perhaps the most useful of such signals is one which shows the words "lift coming" upon an illuminated panel immediately the call button is pressed. Sometimes a position indicator is fitted upon which illuminated figures show where the lift car is located and change as the lift travels through the building. As soon as the button is pressed its associated floor relay on the controller completes an electrical circuit and the position of the floor selecting switch contact—set for the fourth floor—decides the direction of travel. The "down" reverser closes and applies current to the brake-operating magnet and the motor. The brake shoes are lifted clear of the brake drum by the magnet and the motor starts and accelerates at full speed. As the lift travels on its downwards journey, the floor-selector inductor passes in succession the inductor plates at the third, second, and first floors and the magnetic impulses which occur in the inductor switch at each pass cause the selector switch to move one step per floor. The impulses in the other inductor are ineffective since the floor relays associated with the third, second and first floors are not energized. As the ground floor is approached the floor selector moves one further step and this time the impulse in the second inductor switch completes the stopping circuit, the ground-floor



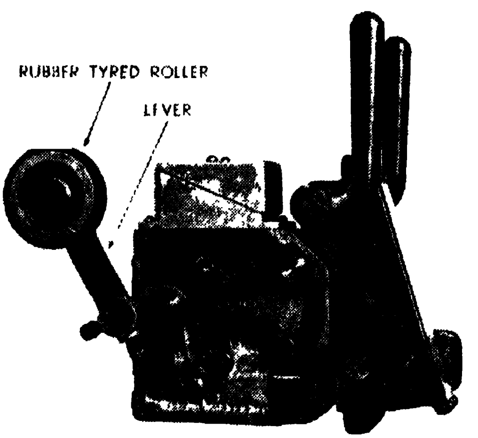
HOW THE BRAKE WORKS

Fig. 8. Should the electric supply fail, the brake is applied mechanically by springs, and is released by a powerful electric magnet housed in an extension of one of the brake shoes.

relay (which was energized when the ground-floor button was pressed) "drops out"; this in turn restores the "down" reverser and cuts off current to the motor and the brake magnet, thus applying the brake. The latter on coming into action stops the car at floor level.

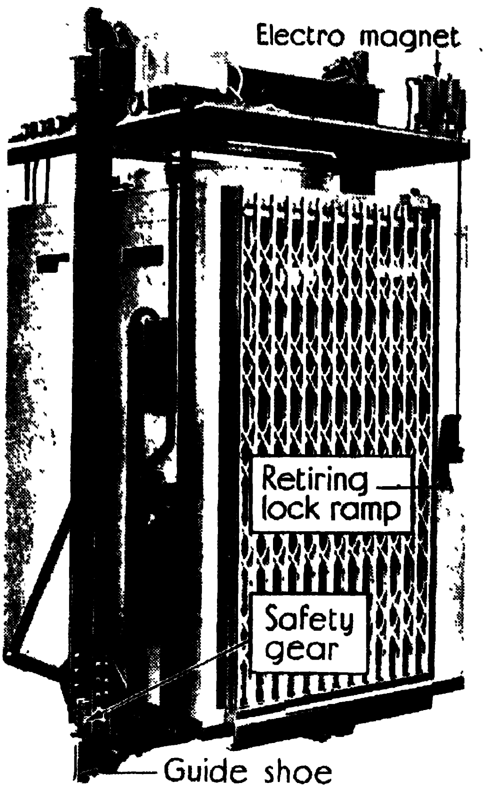
At this stage a further luminous signal may show the words "Lift here" if the landing is protected by solid doors which prevent the passenger from looking into the lift shaft. The arrival of the car automatically unlocks the landing door or gate (as described above) and the passenger, opening the landing door and car gate, enters the car, noting as he does so that the floor may "give" slightly under his feet rather like a weighbridge. The slight movement of the floor operates a switch which establishes an electrical interlock in the controller in order to give a passenger entering the car full control. In other words no other person can operate the lift while the car floor is depressed by the weight of the passenger. Having carefully closed the landing door and car gate, the passenger turns to the car push-button box and presses the button marked with the number of the floor to which he intends to travel. The controller passes through a similar cycle of operations to that described above and the car travels to and stops at the selected floor. It may be wondered how the electric current can be conveyed to the moving lift car. If you look carefully at the underside of the car as the lift travels upwards you will notice a number of thick cables suspended from it and if you are about midway up the building that they connect to a box on the side of the lift well.

A single-speed lift of the type here described would travel at 100 ft. to



LOCK FOR LIFT GATES

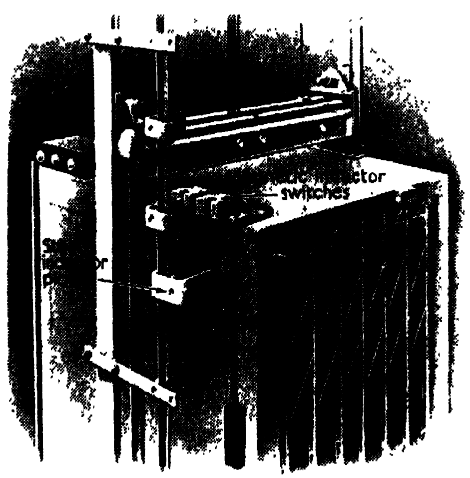
Fig. 9. Most locking mechanisms include a lever with a rubber-tyred roller at the end projecting into the lift well. This lever is pushed aside as the car approaches a floor and the lock is released and the circuit interrupted. The lock illustrated is used for collapsible steel lattice gates.



PASSENGER CAR AND LOCK

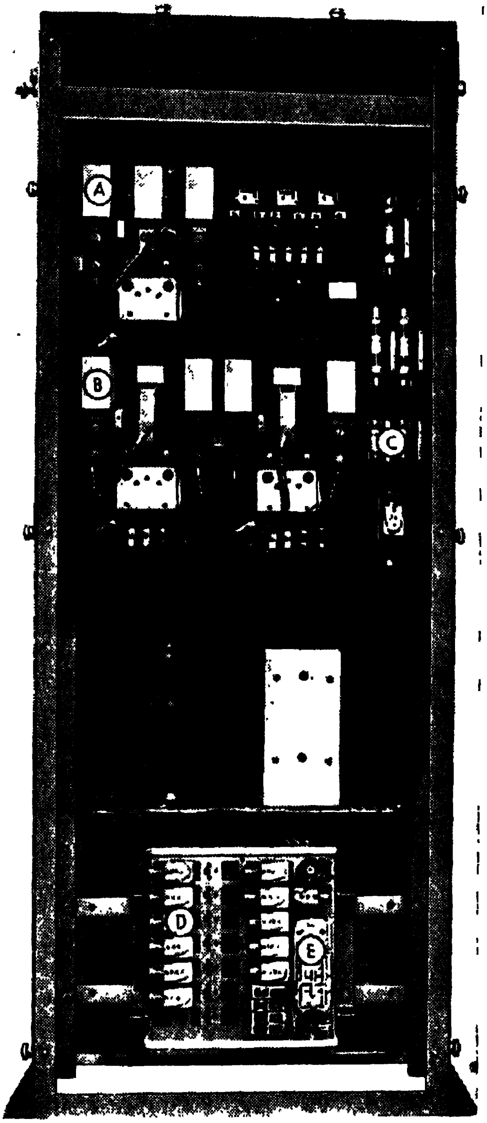
Fig. 10. In this case the lock ramp on the lift car is operated by an electro-magnet on the top of the car. While the car is travelling the magnet is energized and the ramp cannot make contact with the lock rollers. When the car stops the magnet is de-energized, releasing the ramp mechanism which pushes the lock lever aside. The above device is known as a retiring ramp.

120 f.p.m. Fast, attendant-controlled lifts such as are frequently installed in the large department stores travel at speeds between 250 f.p.m. and 400 f.p.m. The highest speed normally encountered does not exceed 500 f.p.m., although there are isolated examples of faster lifts, 700 f.p.m. being the probable maximum. Five hundred feet per minute is about 5¾ m.p.h. The ordinary fully automatic push-button lift such as has been described possesses the drawback that it can deal with only one person, or number of persons having a common destination, at one time, during which they have complete control of the lift to the exclusion of all other potential users. In order to overcome this difficulty and to meet more fully the needs of very busy buildings, other types of automatic lifts have been developed which are the very monuments of ingenuity. As most of these lifts operate on variants of directional collective control, either singly or as groups of lifts electrically interconnected, so that they share the traffic between them automatically to the best advantage, a very brief description of directional collective control is given. The passenger is confronted in this case with two calling buttons on the landing instead of one. The buttons are marked respectively "up" and "down." At the terminal floors, since one can only leave them in one direction a single call push is provided. All calls made by passengers are "registered" in the controller, irrespective of direction or whether the lift be in use or not. If the car is travelling up it will stop at all landings in rotation in response to "up" calls made from them,



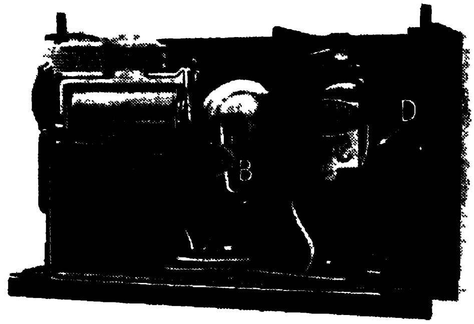
STOPPING AND STARTING THE LIFT

Fig. 11. The two inductor switches fitted on top of the car operate in conjunction with steel inductor plates situated in the lift well, at each floor, and their passage completes an electrical circuit. One inductor switch causes the stepping selector switch to move, while the other one is concerned with the stopping circuit.



BRAIN OF THE AUTOMATIC LIFT

Fig. 12. The controller is a wonderful piece of electrical apparatus, constituting the "brain" of the lift and operating through a number of automatic switches or relays. One of the functions is to select the floor at which the car is required to stop. It determines the direction of rotation of the lift motor, starts it in response to pressure on the push buttons and stops it at the required floor. A single relay associated with each floor informs the controller which floor button has been pressed. A multi-contact stepping selector switch moves one step as the car passes each floor, and informs the controller where the car is situated. The parts lettered are: A, circuit breaker; B, main reversing contractors; C, fuses; D, floor relays; E. multi-contact selector switch.



STRUCTURE OF THE ELECTRIC EYE

Fig. 13. A light beam shines down the tube D and falls upon the light-sensitive cell C. The relay A is operated by the valve amplifier B which amplifies the electric currents generated in C by the action of the light. If the light is obstructed the lift doors, if open, will be prevented from closing until the obstruction is removed, thereby protecting the passenger.

but will not stop to answer "down" calls. As each passenger enters the car he presses the button corresponding to the required floor and the lift continues its upward journey collecting all "up" landing calls and also stopping in response to all car calls.

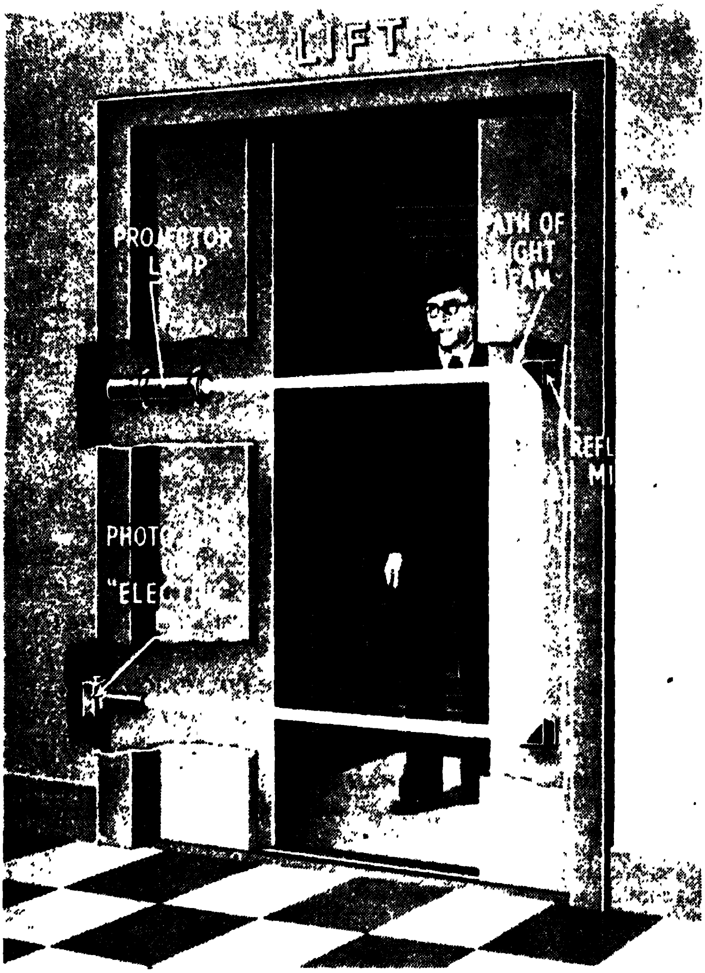
UP AND DOWN CALLS

Having dealt with the "up" calls the car will reverse automatically and deal similarly with the "down" calls that have been made. Perhaps, while the car was travelling up, "up" calls were being made from landings below the position of the car. Such calls are not forgotten, for the car having completed its downward journey will again reverse and deal with the remaining "up" calls. The process continues until all calls have been disposed of. Should a passenger after having made his call go away without waiting for the lift, the car will stop at the landing as usual, but if after a period of a few seconds no one opens the gate and enters the car it will continue its journey.

It is fitting that the automatic electric lift should be associated with one of the outstanding marvels of our age—the

device known popularly as the electric eye. This wonderful contrivance, which fulfils functions so diverse as counting the sheets of paper issuing from printing machines, detecting and removing faulty articles from a moving belt, giving audible warning of incendiary bombs and countless other services is used to protect the passenger in a lift from closing doors. Sometimes the lift doors are operated by electric power and open automatically when the car stops at a landing, closing again when someone calls the lift to another floor or presses a floor button in the lift car. It may thus happen that the doors begin to close as a passenger is crossing the threshold of the lift car. If properly designed the doors should be incapable of inflicting any injury on the passenger, but many people would be alarmed by the closing doors and for their complete protection a light-ray device (Fig. 13) is installed.

A beam of light (actually invisible but shown as a white beam for the purpose of illustration) is projected across the lift entrance and reflected by means of mirrors so as to shine on the photo-cell unit or electric eye (Fig. 14). The minute electric currents generated in the photo-electric cell by the action of the light are amplified by means of a valve amplifier until they are capable of operating a sensitive relay. In the event of the light beam being obstructed by a solid body, the doors, if open, will be prevented from closing until the obstruction is removed. Should the doors be in the act of closing they will stop and reopen to the fullest extent until the removal of the obstruction. Thus complete protection to the passenger is given.



HOW THE ELECTRIC EYE WORKS

Fig. 14. This light-ray device protects the passenger against automatically opening and closing doors. A beam of light (actually invisible but here shown as a white beam) is projected across the entrance of the lift and reflected on to a photo-cell unit as shown in Fig. 13.

HOW AN AIR-CONDITIONING PLANT WORKS

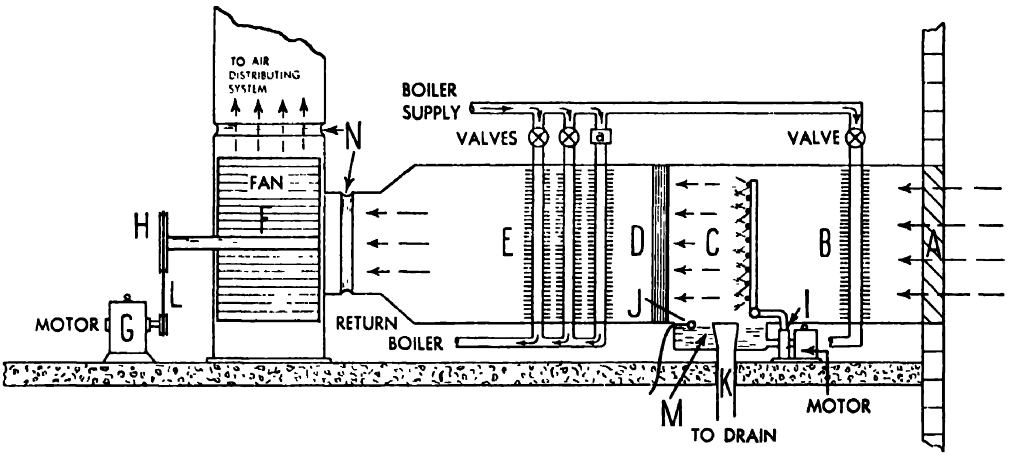
How air is cleaned. The washer. The air heater. Distribution ducts. The extract fan. How even temperature is maintained. Controlling the heater batteries. Air conditioning in summer. Air conditioning in office and domestic buildings.

IT IS only in very recent years that the advantage of cooling air in the summer has taken its place beside that of heating it in winter, and the importance of adequate quantities of air, together with proper degrees of cleanness, moisture and motion, has been distinctly realized. The term "air conditioning" applies to modern methods of controlling these various factors in order to obtain throughout the year indoor conditions satisfying to human comfort and health.

The air-conditioning plant in most of our modern buildings is often referred to as the plenum plant, by which fresh clean warm air is brought into the building during the winter, and cool air during the summer. Running in conjunction with this fresh air apparatus is an extract plant for extracting the vitiated or foul air. The principle of air-conditioning is the same whether applied to large public buildings, commercial premises, hotels or modern office blocks, so to take a typical example, let us select a public building, such as a cinema. When designing the air-conditioning plant, much consideration must be given

EXTERIOR OF AN AIR-CONDITIONING PLANT

Fig. 1. The air-conditioning plant incorporating a large fan is encased by sheet metal. The window enables the engineer to see the air washer, a spray through which air passes, removing impurities.



SECTION OF AN AIR-CONDITIONING PLANT

Fig. 1a. A typical air-conditioning plant is shown in section. Essential parts are: ventilating louvres (A), finned air heaters (B), washer (C), metal plates (D), main heater (E), fan (F), motor (G), pulley (H), electrical-operated pump (I), ball valve (J), overflow pipe (K), belt drive (L), water tank (M), canvas jointing (N). Both motor and fan are well insulated to ensure silent running. The fan is encased by canvas to prevent noise from being transmitted to other parts of the building

to: (1) location (so as to determine the amount of air per person that is to enter the building); (2) seating capacity. In London and large industrial areas, the air is not so fresh as that found in country places or the seaside, so to compensate for this a larger quantity of air is handled in a London cinema than would be the case for a similar size cinema at say a seaside resort. For instance, in London, provision is made for 1,000 cub. ft. of air per seat per hour, but in country places or the seaside 750 cub. ft. of air per seat per hour is ample. It is therefore on these figures that designers calculate.

Let us assume, for example, a cinema in the London area having a seating capacity of 2,000. It will immediately be seen that 1,000 × 2,000 = 2,000,000 cub. ft. of air per hour must be pumped into the cinema by a fan, and further during the winter must be heated (before entering the auditorium) to a temperature not less than 68 degrees Fahrenheit: no small order in frosty weather when one considers that the air is passing through the plenum plant at gale force the whole of the time.

To ensure a good standard of ventilation with modern plants, it is desirable that all fresh air entering the cinema or theatre must pass through the plenum plant and not enter the auditorium by way of doors and exits to cause discomfort to those sitting nearby. To obtain these conditions it is essential that a slight air pressure exists inside the building so that when doors open, air is forced outwards, and to do this the extract fan is arranged to take from the building not more than 75 per cent of the air pumped into the building by the plenum fresh-air fan, therefore 25 per cent of the air must leave by way of doors and exits.

Having selected the air quantity that is to be handled, the next step is to ensure that the air is well distributed and entering the auditorium at: (1) right temperature; (2) correct humidity (moisture in the air); (3) proper air movement (velocity). Therefore the air must pass through the air-conditioning plant and enter the building at not less than 68 degrees Fahrenheit, with a humidity of 57 per cent of the total possible, and a gentle air movement (8 ft. from the floor) of 25 ft. per minute; these conditions will then give a refreshing effect.

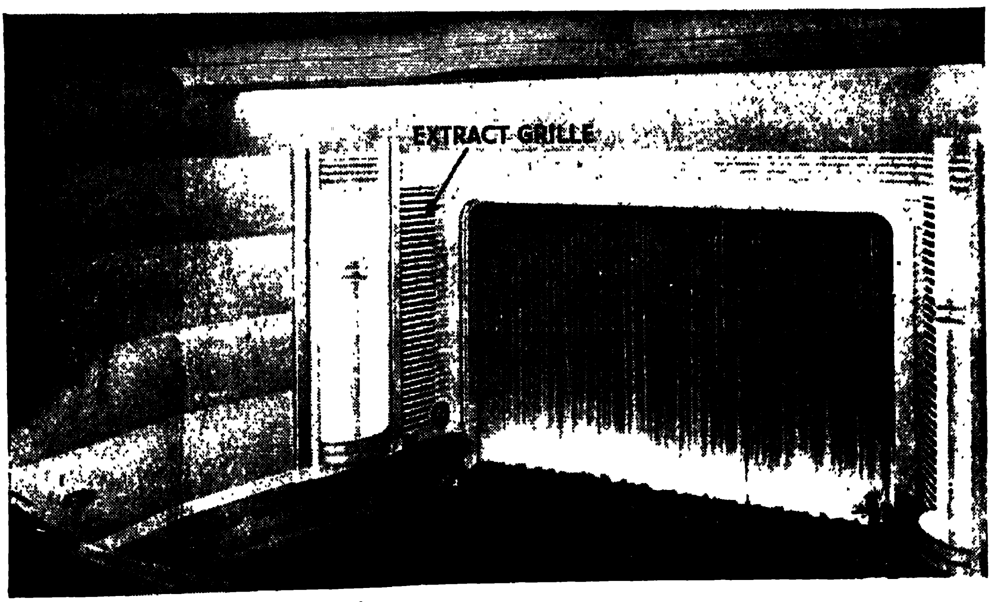
To handle this large quantity of air and at the same time give the desired results, some knowledge of the plant carrying out this task is necessary, so let us look into the plenum room (Fig. 1a).

Here we have a large fan, (F), about 10 ft. diameter, the blades of which are very much like the old water wheel, but instead of wood, steel is used in its construction and the whole fan impeller encased with sheet metal (Fig. 1).

The shaft of this fan is extended through the casing to receive a pulley, (H), which is driven by an electric motor, (G), through the belt drive, (L). Now (M) is a water tank fitted with an ordinary ball valve, (J), which automatically keeps the water at a constant level, any surplus running to waste through the overflow pipe, (K). This water tank comprising part of the apparatus for cleaning the air, has a pipe near the bottom connected to the suction line of an electrically operated pump, (I), the delivery of which forces water into a number of vertical pipes fitted with spray nozzles. From these nozzles a water spray is formed, having a mist appearance, and it is through this mist that the air passes, thus washing out all impurities before entering the cinema. This part is called the washer.

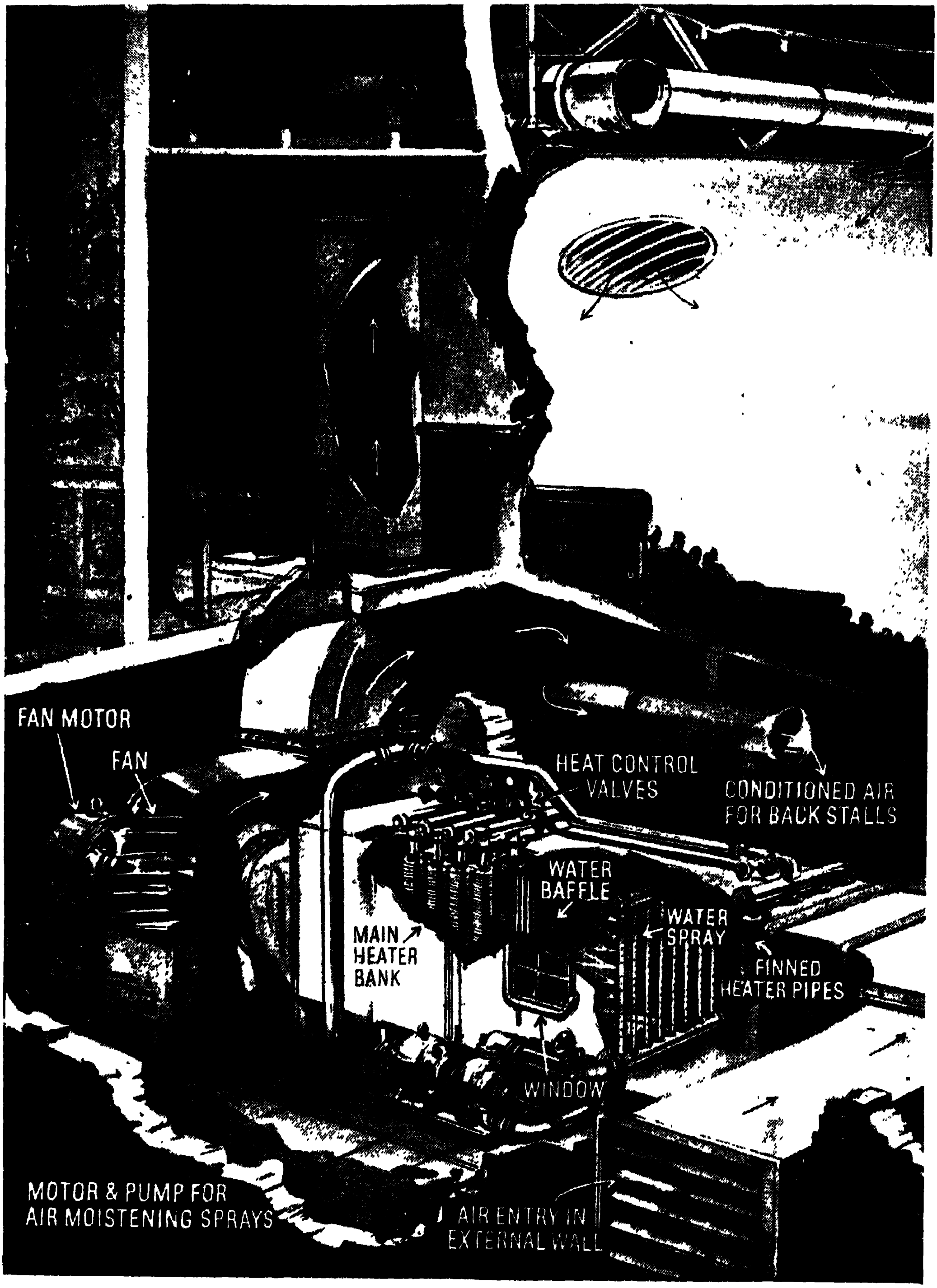
Let us now follow the path of the air through the plenum chamber. Fresh air is drawn through the ventilating louvres, (A), and then passes the first set of finned air heaters (B) (usually referred to as preheaters) and then continues through the washer (C), then past a set of metal plates (D) (to rid the air of surplus moisture), to be again heated by the main (finned) heater, (E). The fresh, washed, heated air then passes through the monster fan (F), to be delivered by metal trunking to various parts of the theatre (Fig. 5).

It should be realized that when dealing with large quantities of air, that apart from the fan, a large motor is required and that both may be situated near to the auditorium in which case special precautions are taken



EXTRACTING USED AIR FROM A CINEMA

Fig. 2. The atmosphere of crowded interiors, as in a cinema, is kept at an even temperature throughout the year, by the type of plant already described. Grilles through which impure air is extracted are seen at each side of the stage. Photograph by courtesy of Odeon Cinemas Limited.



HOW CONDITIONED AIR

Modern city cinemas are provided with 1,000 cub. ft. of air, per seat, per hour, to maintain a good standard of ventilation. This fresh air enters the auditorium by passing through a special plant, in which it is first heated to the correct temperature and washed free of impurities, before being

CIRCULATES IN A CINEMA
pumped into the building by a monster fan, and distributed as shown above through metal trunking. The fan, usually situated near the auditorium, is specially insulated to ensure silent running. Working in conjunction, the extract fan over the screen draws off foul air through the extract grilles.

to ensure silent running, otherwise the whole plant might become a nuisance. Therefore both motor and fan are erected on some sound insulating material and in addition canvas replaces metal either side of the fan, as shown at (N), to prevent noise being transmitted to other parts of the building by way of the metal used for air distribution.

Having seen how the air is conditioned, we now pass on to the distribution system that is usually arranged by means of large metal tubes, approximately 6 ft. diameter, which connect to the discharge side of the fan. These large tubes are usually referred to as ducts. These large ducts start like the trunk of a tree and then branch off in various directions as required, until the smaller ducts, approximately 18 in. in diameter, finally convey the air to architectural grilles, that blend with the scheme of decoration.

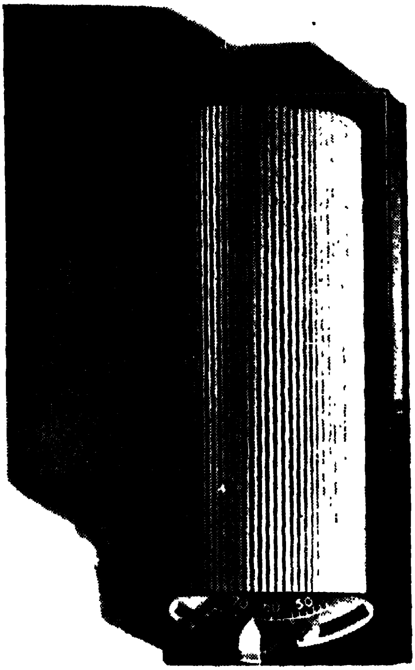
The principle of introducing conditioned air into large buildings can be applied in many ways depending on site conditions, architectural design and local requirements, but the most commonly used methods in theatres and cinemas are as follows: (1) fresh air entering auditorium through grilles at ceiling level and back stalls, extracting the vitiated air on side walls near the stage; (2) fresh air entering auditorium near the stage and extracting vitiated air through grilles in the back circle and back stalls walls; (3) fresh air introduced through grilles at ceiling level and extracting through holes in the floor (usually under the seats). This method is referred to as the "downward system." The most commonly used system in this country is the No. 1 method.

After leaving the discharge side of the fan, the air takes two paths, one feeding the main cross trunking. or duct, situated in the roof space between the auditorium ceiling and the main tiled roof and the other feeding the cross trunking, situated in the void between the balcony and the back stalls ceiling (usually referred to as the balcony void). It should be understood that both these cross trunks, extend practically the full width of the auditorium so that tappings can be taken from them to supply the fresh-air grilles, which also run the full width of the back balcony and back stalls. The reason for extending these grilles in this way is to ensure a good distribution of air to all seats. From one trunk a further extension of the system takes place to feed the other grilles situated in the auditorium ceiling, and from the other trunk, in addition to the supply grille there is another extension feeding grille, extending the full width of the cinema.

By distributing the fresh air in this way the air velocity is naturally reduced to a minimum, which makes it possible to have at least five complete changes of air in the whole of the auditorium every hour (or a change every twelve minutes). This high rate of air exchange gives a clear atmosphere, which assists the showing of clear pictures.

As previously explained, there is an extract system running in conjunction with the conditioned air-input system, and the extract fan over the stage, is connected to a cross trunking, from which trunk tappings are taken to the extract grilles on the two side walls front stalls. One of these grilles is shown in photograph (Fig. 2).

It should be pointed out that the speed of both the fresh air and extract fans can be varied slightly by the arrangements of speed control on the respective motors. This enables the air quantity to be varied according to the size of the audience, to maintain an even inside temperature; the boilers are connected by means of pipes to two main heating branches as follows: (1) the ordinary hot-water radiator system that supplies offices,



AUTOMATIC CONTROL SWITCH

Fig. 3. A thermostatic control switch in the auditorium operates automatically to maintain temperature at a predetermined level.

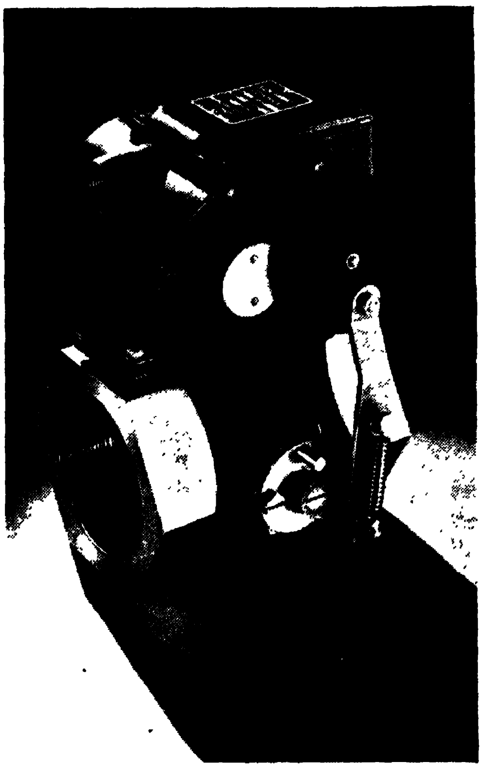
pay boxes, dressing-rooms, store-room and auditorium so that an even temperature can be maintained in these parts when the air-conditioning plant is shut down; (2) the air-heater batteries of the air-conditioning plant. The hot-water radiator system, well known as a means for giving direct heating will not be discussed here, as our main object is the air-conditioning plant and the way in which it operates.

The finned air-heater batteries (Fig. 1a) are designed for the maximum conditions of raising the incoming fresh air temperature from 32 degrees Fahrenheit to approximately 85 degrees Fahrenheit while the air is passing through the plant, but there are times when the outside temperature is much higher than 32 degrees Fahrenheit in which case the heat required must be cut down if an even temperature is to be maintained. Therefore the air-heater battery is arranged into a number of banks separately controlled.

One section of the heater bank should be controlled by an automatic switch, situated in the auditorium, similar to that shown in Fig. 3. This switch (known as a thermostat) can be set to operate at any predetermined temperature such as 68 degrees Fahrenheit (which is usually a comfortable indoor temperature).

CONTROLLING THE TEMPERATURE

Working in conjunction with this automatic switch is a motor-operated automatic valve, (Fig. 4), on one of the air-heater banks of the air-conditioning plant as shown at (A), (Fig. 1a). Should, therefore, the inside temperature rise



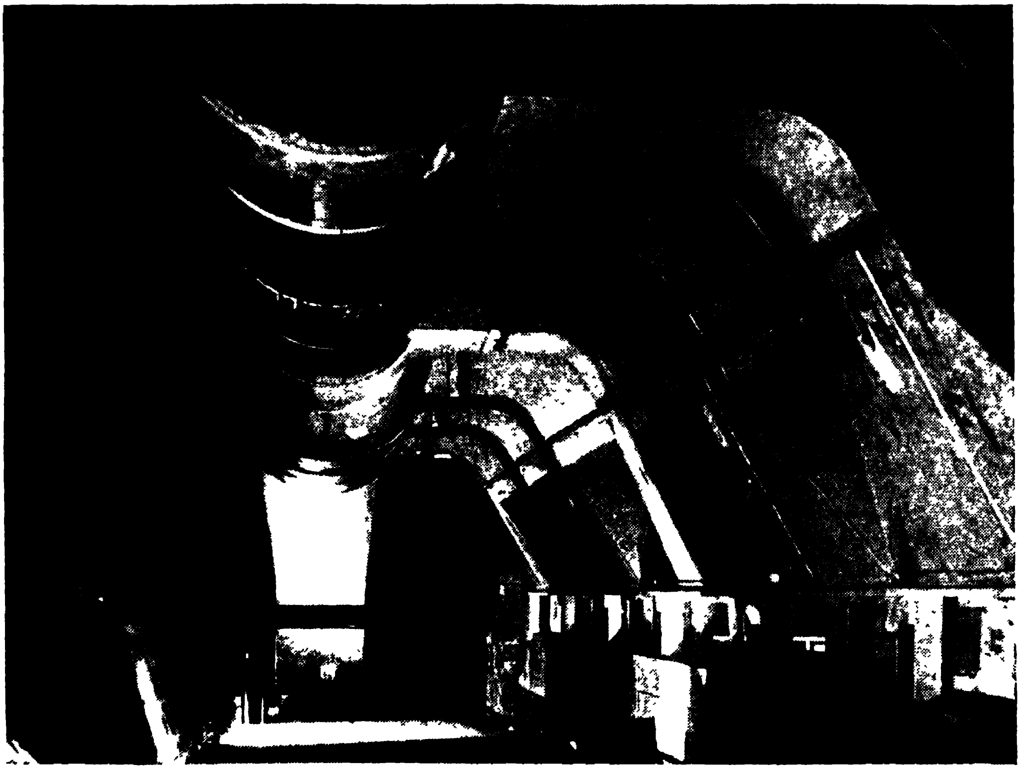
MOTOR-OPERATED AUTOMATIC VALVE

Fig. 4. A motor-operated automatic valve working in conjunction with the thermostat, closes, and reduces the heating of the incoming air, should the inside temperature rise above the level at which the valve has been set to operate.

above 68 degrees Fahrenheit, the automatic switch will come into operation together with the automatic valve on the plant, causing the valve to close and reduce the heating of the incoming air; the valves on either side of (A), Fig. 1a, being ordinary hand valves, will remain open or shut as left by the person in charge. Should, on the other hand, the inside temperature drop below 68 degrees Fahrenheit, the automatic switch will again respond, but this time the automatic valve will open to give the necessary extra heat to the incoming air, restoring the auditorium temperature.

During the very hot weather of course some attempt has to be made to cool the air entering the hall, and this is usually done while the air passes through the air-washer, but the heat given up to the water by the air must be dissipated so it is essential that the water be constantly changed or cooled. If the water is to be changed this can be done by taking a supply from a well under the building, as well-water temperature is usually about 45 degrees Fahrenheit.

In an office building the fresh air is drawn through fresh-air louvres at the top of the building to pass down a shaft to be conditioned. The air is then sent up the main air shaft by a fan.



BREATHING TUBES OF AN AIR-CONDITIONED BUILDING

Fig. 5. Massive metal tubes of the type shown in this illustration make up a system of trunking through which the impure air is carried to the extract grilles found in all parts of the building.

Great Britain has few air-conditioned domestic premises, but in America where higher summer temperatures are recorded, small cabinet units (about the size of an ice-cream container) are used for one or two rooms. These cabinets are in principle the same as the larger plants and in some cases are made portable.

HOW YOUR RADIO SET WORKS

Sound and the microphone. The radio "carrier" wave. Selecting the frequency. How valves work. Frequency conversion in the superhet. Demodulation. The output transformer and loudspeaker. Push-button tuning. Gramophone pick-ups.

BECAUSE they cannot "see the wheels go round" people think radio sets are harder to understand than they really are. Actually there are quite a lot of mechanical effects associated with the electrical processes in a receiver, and the processes themselves correspond to mechanical devices in a remarkable way. For example, a receiver divides into a series of stages, each built round a valve, and which can be thought of as a series of meshed gears.

However, let us start right at the beginning of the radio chain—the microphone in the studio. "Mikes" are of many kinds, but in the moving-coil type there is a diaphragm which vibrates under the impact of the sound waves and makes a coil of fine wire move, piston-like, in a highly intense magnetic field.

Now when a coil moves in a magnetic field, a current is induced in it, and the microphone current varies in such a way that it forms an electrical copy of the sound. Incidentally, although the current may vary from fifty to 15,000 times a second, it is called low frequency. We shall soon understand why.

The task now is to convey the shape of this current to the millions of receivers. We cannot broadcast the current itself, but we can use it to regulate the strength of a radio wave. This wave will, therefore, act as a kind of messenger and it is often called a "carrier" wave.

Radio waves wing through space—we used to say the ether—at the speed of light, 300,000,000 metres a second. How are they produced? Simply by making a current oscillate, or alternate, in the transmitting aerial.

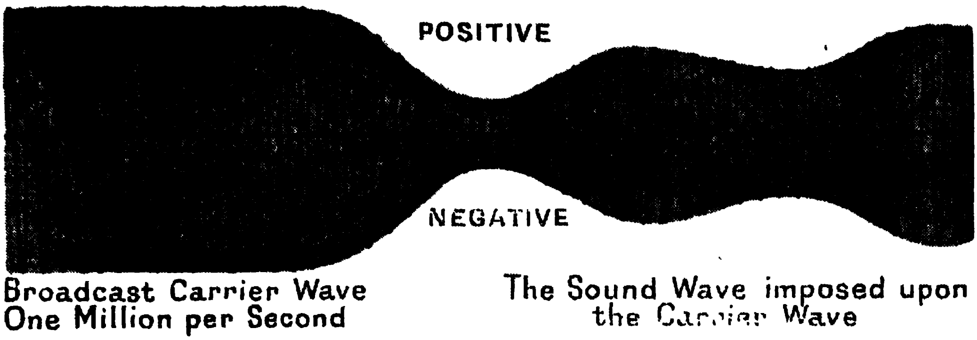
But, you may say, an electric mains current alternates without broadcasting. Quite so. But there is this difference: a mains supply alternates at, say, 50 cycles a second, while radio currents do so anything from hundreds of thousands to millions of times a second.

In a way which will be suggested later, we can generate an oscillating current, and, therefore, a radio wave, at any suitable desired frequency. If we decide to transmit a million vibrations, or cycles, per second, we have only to divide this frequency into the speed to find the length of each cycle, or wave. In this case the wave length will be 300,000,000 divided by 1,000,000, i.e., 300 metres.

The pure radio wave is regular in frequency, and the peaks of all the cycles are of uniform amplitude, or strength.

Now this radio wave, unlike the sound wave, will be a perfect alternation, regular in both frequency and amplitude. We do not let it remain so. Instead, we vary its amplitude at the slower frequency of our sound waves (Fig. 1).

This modulated wave, as it speeds along, consists of electric and magnetic



HOW A RADIO WAVE ACTS AS A CARRIER OF LOW FREQUENCIES

Fig. 1. The wavy line represents the variations of strength of a radio wave oscillating between positive and negative values a million times a second. At first the wave is not modulated, but the right-hand section shows how the amplitude of the oscillation is made to change at low-frequency rate

stresses which have the power to act upon the electrons in receiving aerials.

Electrons are negative particles of electricity and are a part of the "bricks" of which all material things are made. In good electric conductors there are vast numbers of more or less free electrons which, given a common incentive, will all move together and form an electric current.

Electrons have two kinds of effects on the space round them, and we call these effects, electric and magnetic fields. Through these fields electrons repel each other, or are attracted to positive regions—areas where there is a shortage of electrons. At the same time electric and magnetic fields from outside, by reacting against the electrons' own fields, can push the electrons about; and this is what happens as a radio wave passes an aerial.

There are, of course, hundreds of waves passing any aerial, and accordingly there are hundreds of oscillating aerial currents. Somehow we have to sort out the required frequency. The device which does this is the tuned, or resonant, circuit. This sounds formidable, but is simply a coil with a condenser connected across it.

A tuning coil (Fig. 2) consists of turns of wire on a tubular former. The number of turns depends on the band of frequencies over which we wish to tune. Generally, the two or three windings are on a single former, all being used on long waves, and sections being cut out by a parallel switch as the lower waves (medium and short) are required.

The coil is not direct in the aerial lead, but has currents induced in it by coupling windings to which the aerial is actually connected. This reduces certain unhelpful effects of the aerial on the tuned circuit. As the aerial currents oscillate in the coupling coil they create a varying magnetic field, and this, cutting the turns of the tuning coil, produces similar currents in it. It is the principle of induction already mentioned in connexion with the microphone, only carried a step further.

The variable condenser across the coil consists of two large metal plates arranged in two assemblies of small vanes and made so that one set can be meshed within the other to any desired degree (Fig. 3). There is a narrow air space between the two sets of vanes.

How does connecting this condenser across the coil enable us to select the required frequency? First, imagine an oscillating current exists in the coil. As this flows in one direction it will charge up the condenser so that one

plate is negative and the other positive.

As soon as the driving force (the signal voltage) begins to decline, the condenser starts to discharge, and the electrons rush from the negative plate into the coil on their way to the positive plate. It might be thought that they would simply flow to the positive and make up the deficiency of electrons. However, as the electrons surged into the coil they build up round it a magnetic field, and when the rush begins to slow down, this field collapses inward, cutting the turns of the coil and inducing a current which maintains the flow until the condenser is recharged, but in the reverse direction.

Once again the condenser discharges, and again the coil makes the current flow on until the condenser is recharged. And so the process continues, the current flowing backwards and forwards and the energy circuit swinging between the electric field of the condenser and the magnetic field of the coil.

For a condenser and coil of certain sizes this exchange of energy, resonance as it is called, occurs at only one particular frequency. And when just this one frequency is induced from the aerial into the coil, an oscillatory current —much larger than those currents which other frequencies can produce—is quickly built up.

Although we have talked of the current flow, it is the voltage the current produces across the condenser and coil which is of importance. Because of the build up of current, the voltage attained is considerably greater than the voltage in the aerial. As well as responding solely to one signal, therefore, the tuned circuit also magnifies.

Very much more magnification is necessary, however, and for this we call upon the valve.

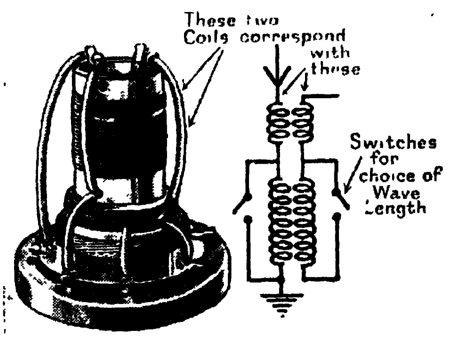
If we take a simple valve for operation from batteries we find it consists of: (a) a glass bulb from which the air has been exhausted, (b) a filament which is heated from a low voltage (low tension) accumulator, (c) a metal plate, or anode, and (d) a fine wire mesh, or grid, between filament and anode.

By connecting a second battery (usually a high-voltage dry battery) between anode and filament, we can make the anode either positive or negative with respect to the filament. A meter would show that current flows when, first, the filament is heated, and secondly, when the anode is positive. Evidently heating the filament weakens the bonds holding the electrons, and the positive anode draws them across the valve (Fig. 4 illustrates this).

The H.T. (high tension = high voltage) battery alone provides this anode current and the L.T. battery simply heats the filament. This independence of the two currents is seen clearly in the mains valve.

The latter is heated by raw current from the mains, and to get smooth heating the filament is employed as a heater inside a metal tube, or cathode. This supplies the anode current and is connected to H.T. negative.

Since current can only pass one way—from filament to anode—we now see why the device is called a valve. More than this, it is a very finely adjustable valve.

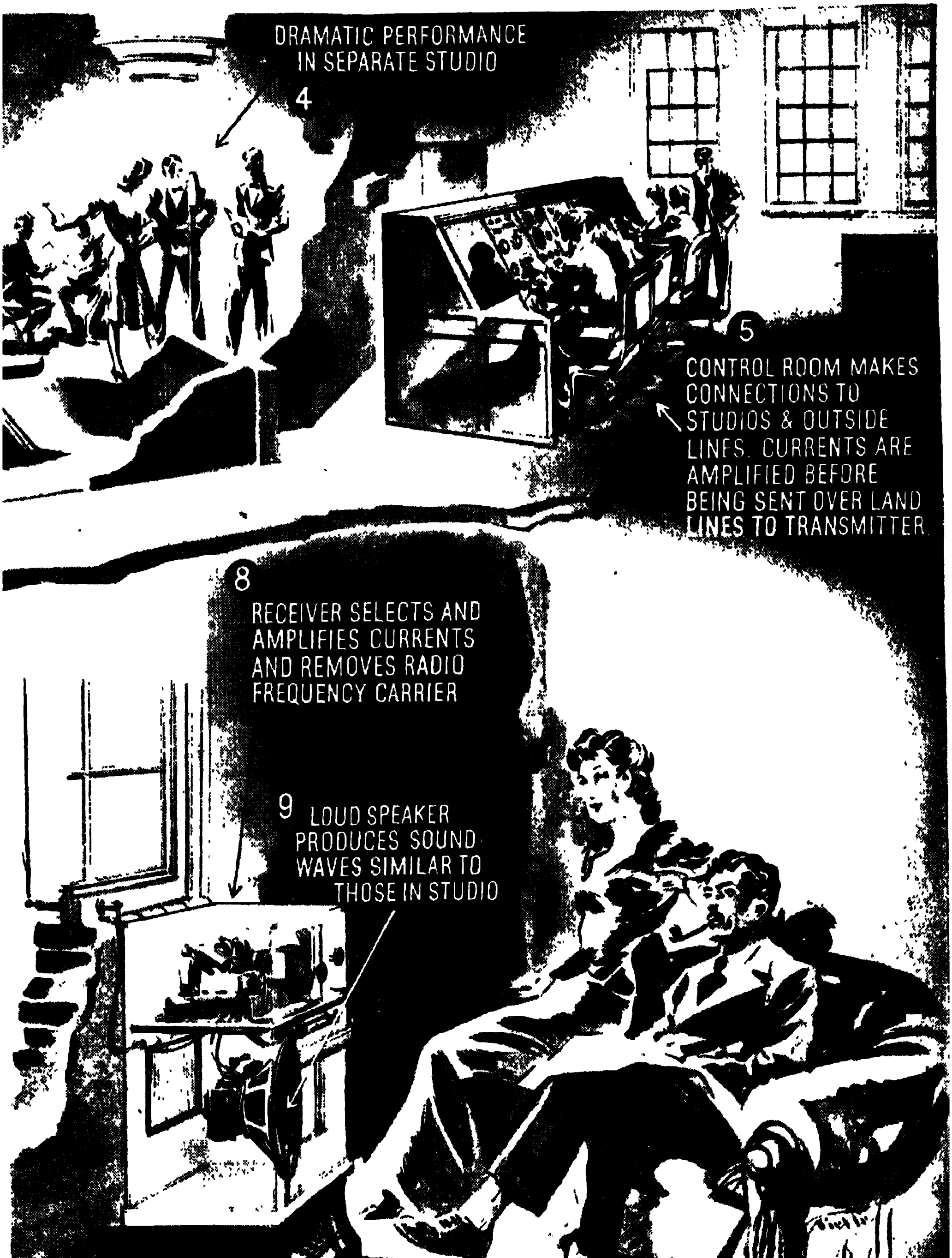


A TWO-WAVEBAND COIL

Fig. 2. Typical medium- and long-wave tuning coil with two aerial coupling windings. For medium waves, the long-wave windings are short-circuited by switches as illustrated.

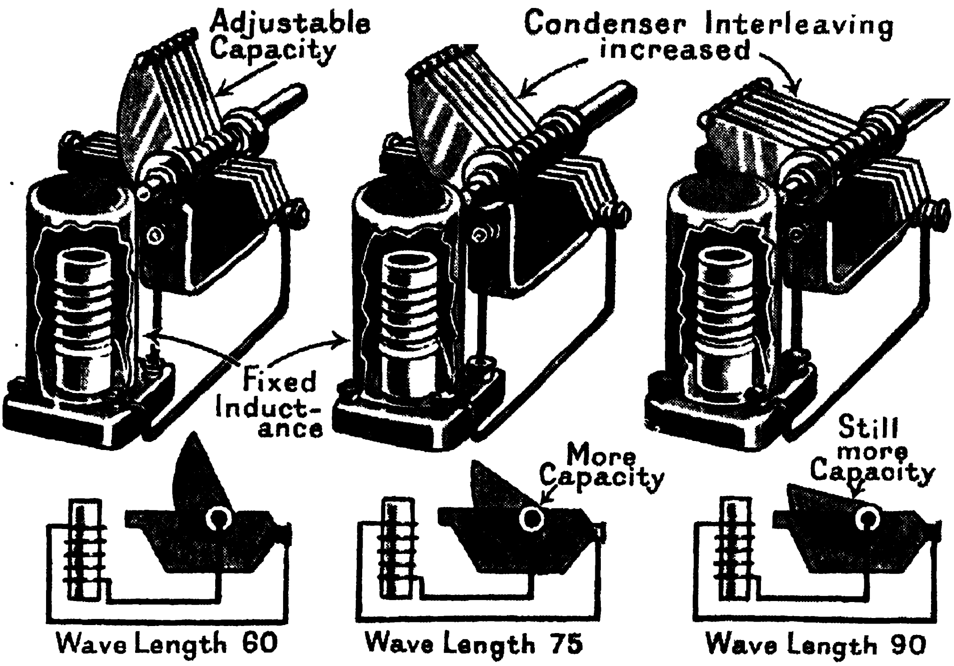
MAIN STAGES IN THE TRANSMISSION OF SOUND FROM

Inside the broadcasting studio, the sound vibrations made by the performers form an electrical copy by inducing a current in the moving coil microphone. This sound passes to the control room, where the currents are amplified before being connected with the outside land lines.



BROADCASTING STUDIO TO MILLIONS OF LISTENERS

These currents regulate the strength of the carrier waves, which wing through space from broadcasting aerial to receiver at the speed of light. In the moving coil loud speaker, a process similar, but reverse to that in the microphone, is set up, and sound waves are again produced.



TUNING IN YOUR FAVOURITE PROGRAMME

Fig. 3. Here you see the essentials of a tuned circuit—a coil and a variable condenser. The diagrams show the same two components with the variable condenser in three different positions. As the vanes mesh further, the capacity is increased and the circuit responds to a higher wave length.

This is where the grid, the wire mesh between filament and anode, comes in.

If we use a third battery between grid and filament (or cathode) we can make the grid positive or negative. In the former case it will act as a second anode; but suppose we make it negative?

Things become interesting. The negative electrons on the grid oppose those on the filament and screen them from the attraction of the anode. The electron stream is reduced, and by making the grid increasingly negative we can cut the anode current right down to zero if required (Fig. 5). By suitably designing the valve we can arrange matters so that a small change in *voltage* on the grid produces a big change of anode *current*.

The three-electrode valve just described is called a triode. There are numerous valves with extra grids, or screens (Fig. 6), inserted in order to ensure that the electrons go where required without bouncing around.

There are screen-grid, or tetrode (four electrode), valves, pentodes (five electrodes), octodes (eight), and types consisting of two or more in a single bulb.

After this excursion we can now return to our tuned circuit and see how a valve is used to amplify the signal voltages. By connecting the circuit between grid and filament we can make the signal regulate the anode current, and by placing a second tuned circuit, adjusted to the same frequency, in the anode path we can develop a greatly amplified voltage.

Usually, a screen-grid, or pentode, valve is employed, and another practical point is this: the signal voltage oscillates between negative and positive—but, as we have seen, the grid must not become positive. What we do, then, is to give the grid a steady negative

bias (by means of a grid-bias battery in a battery set) so that a positive signal only makes the grid *less negative.*

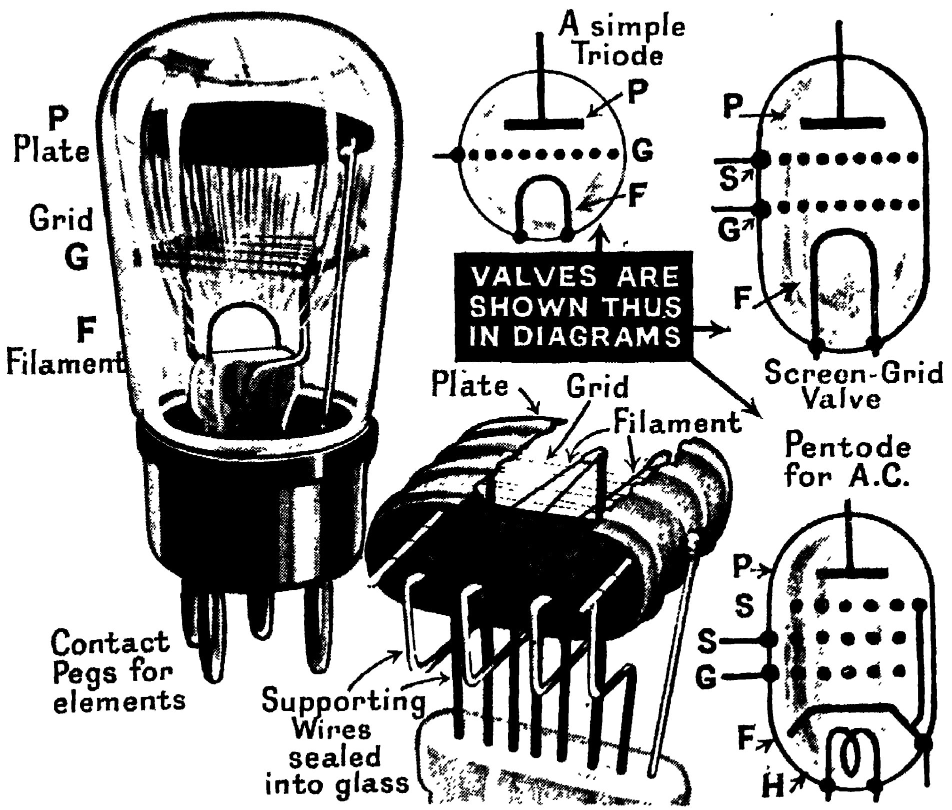
There are so many powerful transmitters that one tuned circuit is not sufficient to pick a particular station out of the jumble. Years ago two tuned circuits were coupled together in front of the valve, and sometimes a further two circuits after it were tried. However, for convenient tuning it was necessary to have all the condensers ganged on a single shaft, and it was found that a four-gang condenser was both expensive and very difficult to make with accuracy.

The tuned radio-frequency, or straight set, has now largely given way to the super-heterodyne receiver or "superhet."

In this type of set each station, after it has been roughly tuned, and whatever its frequency, is converted to a new intermediate frequency (I.F.). As the I.F. is always the same it is amplified by a valve preceded and followed by tuned circuits which need no adjustment.

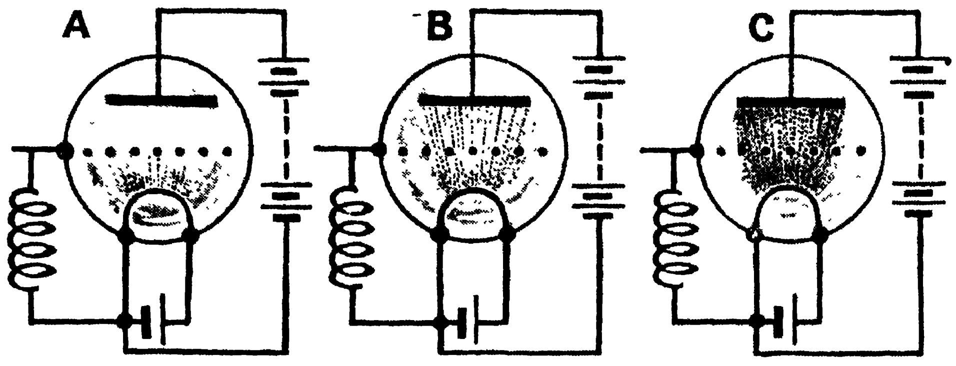
This I.F. is produced in a valve called a frequency converter. Usually it consists of two valves in one bulb. The first is a screen-grid, tetrode, or heptode connected to amplify the signal and, perhaps, preceded by two tuned circuits.

The second valve is a triode which generates a radio-frequency similar to



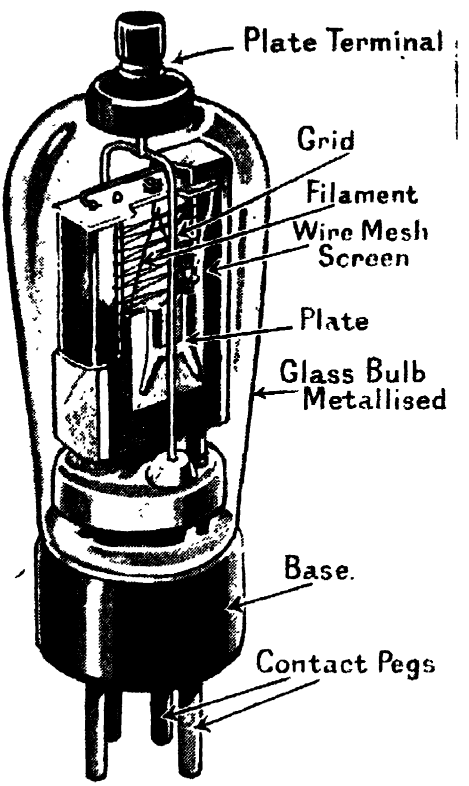
ELEMENTS OF THE VALVE AND HOW IT WORKS

Fig. 4. On the left an impression of a triode valve illustrates how the electrons drawn from the filament to the positive plate or anode have to pass through the control grid. Sometimes the electrodes are horizontally mounted, as shown in the second drawing. The other diagrams show valves, as they are represented in circuit drawings.



THE ACTION OF THE VALVE

Fig. 5. Three diagrams indicating how the flow of electrons from filament to anode is controlled by the signal applied to the grid. In A the grid is very negative and the anode current is completely checked. At B and C the grid is progressively less negative and the current correspondingly greater.



A SCREEN-GRID VALVE

Fig. 6. This type of valve has a second, or screen-grid interposed to prevent electrons bouncing back from the anode on to the control grid. The addition of the screen made large high-frequency amplification possible as previously the triode had not been satisfactory for this work.

the kind generated by broadcasting transmitters, but much less powerful.

The triode is made to do this by connecting a tuned circuit between grid and filament and magnetically coupling the grid coil to a coil in the anode circuit. It is not difficult to see what happens. In the case of the aerial tuned circuit the signal starts and maintains the oscillation; in this instance, the drive is provided by energy fed back from the anode, and, needless to say, it will always be in step, since the anode current itself is controlled by the grid circuit.

By connecting the triode grid internally to one of the screen electrodes, this local oscillation is injected into the amplifier valve.

The filament-anode electron stream is now controlled by both signal and injected frequencies. If of the same frequency they would either add together or cancel out, but the injected frequency is made slightly higher than the other, and the result is that they add, or cancel, not on every cycle but only every so often. The result is the production of two new frequencies, one consisting of signal and oscillator frequencies added, and the other of these frequencies subtracted.

Beat frequencies, as they are called,

are easier to understand when you know they also occur with sound waves. If you strike two suitable low notes on the piano you will clearly hear a deep throbbing beat note. The effect is sometimes used by organists to get that impressive, floor-shaking drone.

Suppose we decide the I.F. frequency shall be 450,000 cycles (450 kilocycles as we usually say: kilo = 1,000). When receiving a 1,000 k.c. (300 metre) station our oscillator frequency could be either 550 k.c. or 1,450 k.c. In practice the latter would be used because an oscillator circuit with a higher frequency is easier to gang-tune with the aerial circuits.

It will be appreciated that the oscillator circuit must be variably tuned so that its frequency is always 450 k.c. above that of the signal.

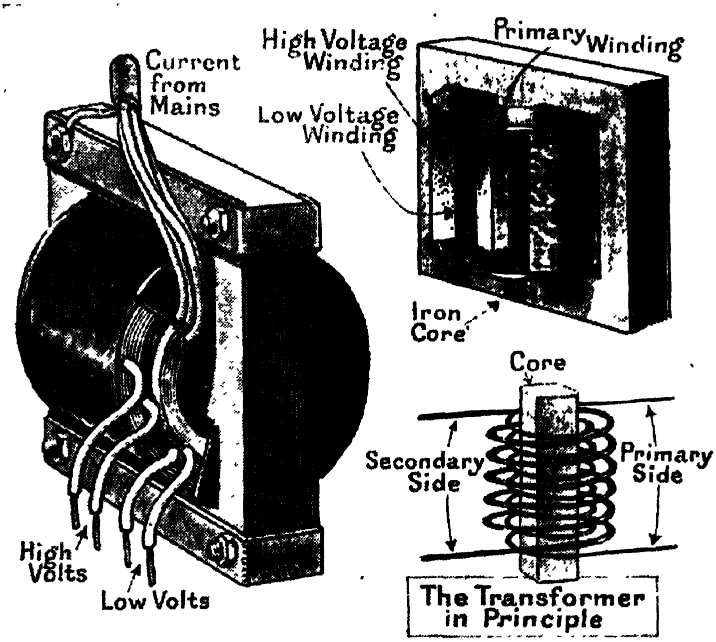
The I.F. signal in the anode circuit of the frequency-changer is now made to produce a voltage in the first I.F. tuned circuit. Still further amplification is required so the signal is transferred, by induction, to the coil of a second tuned circuit. These two coupled circuits are called an I.F. transformer. They increase selectivity and also prevent the positive anode voltage of the first valve being applied to the negative grid of the second.

After the I.F. amplifier valve, a pentode, or screen-grid, type, the signal passes through a second I.F. transformer. Although now magnified, it is not suitable to operate a loudspeaker.

The first thing to do is to remove the radio carrier frequency in such a way that we only have the low-frequency signal left. This is done by a process variously known as detection, rectification and demodulation.

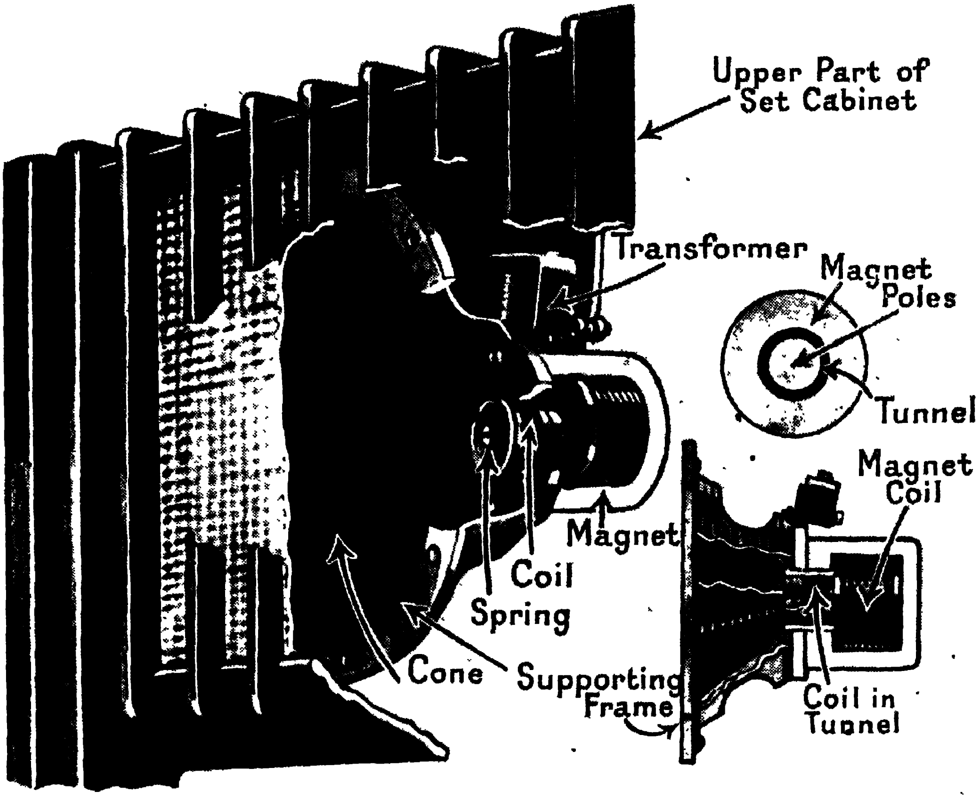
In the old straight sets a triode valve was used for this job, but today a diode is employed, as it handles bigger signals with less distortion. A diode consists simply of a filament and an anode, and as we have seen, a valve conducts only when the anode is positive.

Simply by applying our signal between anode and filament of a diode, we cut off all the negative halves of the cycles. This leaves us with radio



THE TRANSFORMER IN PRINCIPLE AND PRACTICE

Fig. 7. A transformer consists of two or more windings. When a varying current is passed through one, similar currents of different voltage appear in the other "secondary" windings. Low-frequency types such as mains and output transformers have iron cores as shown here; radio and intermediate-frequency types are usually air-cored, but sometimes they have a core of iron dust and this core is embedded in wax.



STRUCTURE OF A MOVING-COIL SPEAKER

Fig. 8. Sound-waves are set up by vibrations of the diaphragm which is driven by a coil carrying the amplified output current and moving in a magnetic field. In the "energized" type of speaker, the field is produced by an electro-magnet, the winding of which usually acts also as the H.T. smoothing choke. The part labelled "spring," but more accurately called a "centring spider," carries out the function of keeping the coil in a central position in the magnet gap.

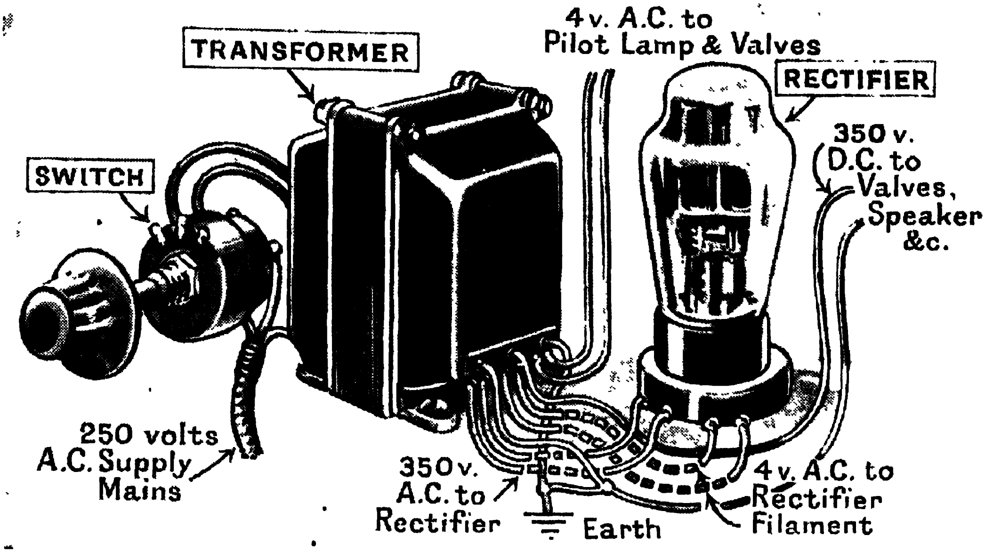
frequency pulses varying in amplitude at the low frequency of speech or music.

Next, we include a condenser, which the pulses can charge up, and we also provide a resistance so that the charge can drain steadily away. The result is that the charge in the condenser—and the voltage across it—always represents the strength of the modulation.

This diode valve is usually included in a single bulb with another diode and a triode. The second diode works in the same way as the first, but the L.F., as well as the H.F., is smoothed out and a voltage representing the *average* value of the signal is obtained. This voltage is employed to vary the grid bias of the frequency changer and I.F. amplifier valves, which are special variable-mu types, i.e., their amplification is controllable by their bias.

Matters are arranged so that if the average strength of the signal rises above a predetermined level, the amplification of the valves is reduced. Then, as soon as the signal declines, the valves are permitted to provide increased amplification. This system of automatic volume control aims at providing a steady output of sound regardless of any fading.

The triode section of the third valve in the set amplifies the low-frequency voltage obtained from the demodulation



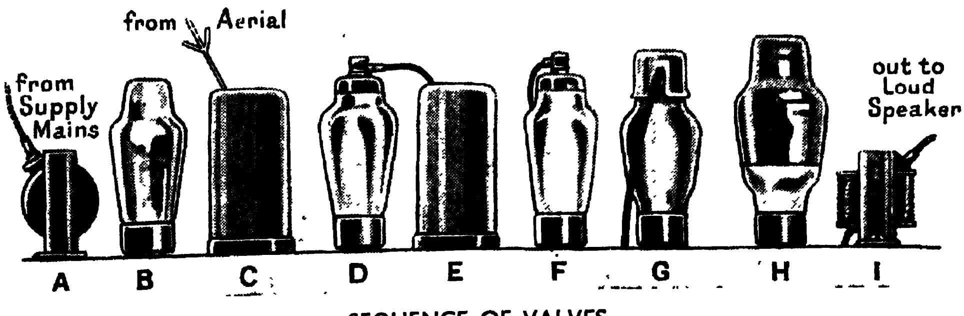
ADAPTING MAINS CURRENT TO OPERATE A RECEIVER

Fig. 9. A.C. mains are connected to a set by means of a transformer which supplies a low voltage for the valve heaters and also a high voltage which, after conversion by the rectifier valve, provides the high-tension current. A fourth winding provides a separate supply for the rectifier filament.

condenser. In the anode path of the triode is a resistor, and as the varying anode current passes it produces an amplified L.F. voltage. The anode side of the resistance is connected to one side of a condenser, which passes the signal on to the grid of the last valve.

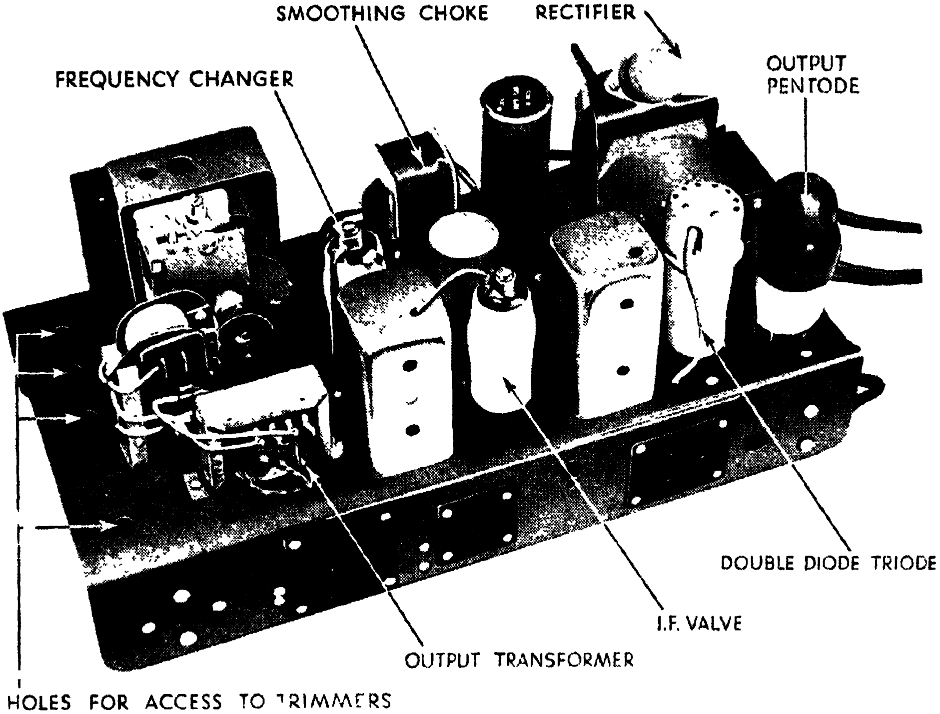
The condenser is needed to isolate the positive anode from the succeeding negative grid, and the voltage is transferred, not by a magnetic field as in the I.F. transformer, but by the electric field between the plates of the condenser.

The special thing about the output valve is that it is designed to pass a large anode current. So far we have only been concerned with amplifying a voltage, but now we have got to provide power to do the mechanical work of driving the loudspeaker diaphragm and setting up sound waves. For this a good



SEQUENCE OF VALVES

Fig. 10. In an A.C. mains set the anode and heater currents are first obtained by means of the mains transformer and rectifier, A and B. The signal from the aerial is tuned in coil C and then converted to the intermediate frequency in D. E is the first I.F. transformer, and the amplifier F is coupled by a second transformer (not shown) to demodulator G. The low-frequency is now amplified by output valve H, which feeds the loudspeaker through the transformer I. The sequence is shown above.



WHAT'S WHAT IN A TYPICAL SUPERHET CHASSIS

Fig. 11. A view of the surface of a receiver chassis. The aerial and oscillator coils and the waveband switching are "below deck," together with sundry small resistances and condensers

strong anode current is necessary.

The varying current of the output valve is generally passed, not direct to the loudspeaker, but to a low-frequency transformer, a component consisting of two coils on an iron core (Fig. 7).

Flowing in one winding—the primary—the valve current induces a similar current in the secondary. By having fewer turns on the latter we get a reduction of voltage but a commensurate increase of current. As all the power in the anode current has to be transferred to the secondary current, the magnetic field has to be very intense, and the iron core is employed to concentrate the field within the coils.

So we arrive at the loudspeaker (Fig. 8). This is like the moving-coil microphone already described but in reverse. Instead of the diaphragm moving the coil and inducing a current, we supply the current to the coil, and this makes the diaphragm move in and out, so setting up sound waves similar to those which started the whole story.

In order that the magnetic field in which the coil moves shall be very strong, the coil is situated in a narrow annular gap or tunnel. As the space is so limited there cannot be many turns on the coil, and the current through it must be as heavy as possible. This is the reason for the step-down output transformer just described.

Nowadays, most receivers operate straight from either A.C. or D.C. mains, and we must note their special features.

Owing to the special construction of mains valves, the filaments are easily run from the mains. Sometimes they are joined in series with the current limited

to a suitable value by a resistance. More often they are fed with A.C. of 4 or 6·2 volts from a secondary winding of a mains transformer (Fig. 9).

Such a transformer is the same in principle as the output type, but it carries three or more secondaries, and is large and weighty as all the power to operate the receiver passes through it.

A big advantage is that just as one winding will step-down the voltage below the mains pressure, another by having a greater number of turns can be made to give a higher voltage. This is valuable in enabling us to get a high voltage for the anodes of the valves.

Most A.C. supplies alternate at 50 cycles a second, and if the transformed voltage was applied straight to the set all we would hear would be a violent 50-cycle bass note. The current has first to be changed into direct current.

Once again we employ the diode valve—but this mains rectifier is much larger than the demodulator type—and, moreover, we generally use two in one bulb in an ingenious circuit which gives full-wave rectification. Instead of just lopping off half of each cycle we turn it round so that instead of 50 alternating cycles per second, we get 100 pulses, all in the same direction.

This current is still far from steady, so we make it flow through a smoothing circuit. First, there is a big capacity condenser into which the pulses pour, next there is a large iron-cored coil, or choke, which permits a steady current but strongly objects to any sudden changes, and, finally, there is another large capacity condenser from which current issues smoothly to the anode circuits. Often the choke is also the electro-magnet winding providing the magnetic field of the moving-coil speaker.

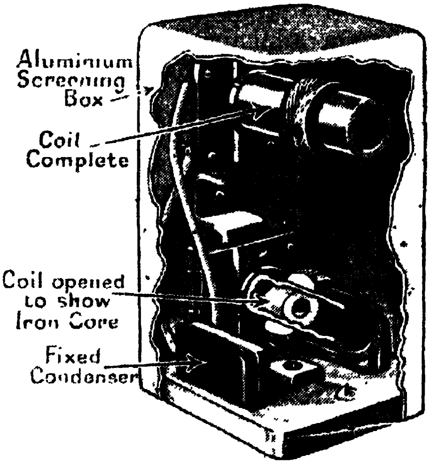
Mains valves also have automatic grid bias. The current from the cathode to H.T. negative is made to go through a resistance. The voltage across this makes the cathode positive, which is the same as making the grid negative.

There are now quite a lot of universal sets, that is, ones which work from either A.C. or D.C. As D.C. will not operate a transformer (which depends on the magnetic action of a constantly varying current), the mains supply is taken direct to a single-diode rectifier. On A.C., half of every cycle is not employed, and on D.C. the current, provided the mains are connected so that the anode is positive, simply flows straight through the valve.

We have now come to the end of the chain of valve stages (Fig. 10) which comprise the average receiver. Fig. 11 shows the receiver chassis.

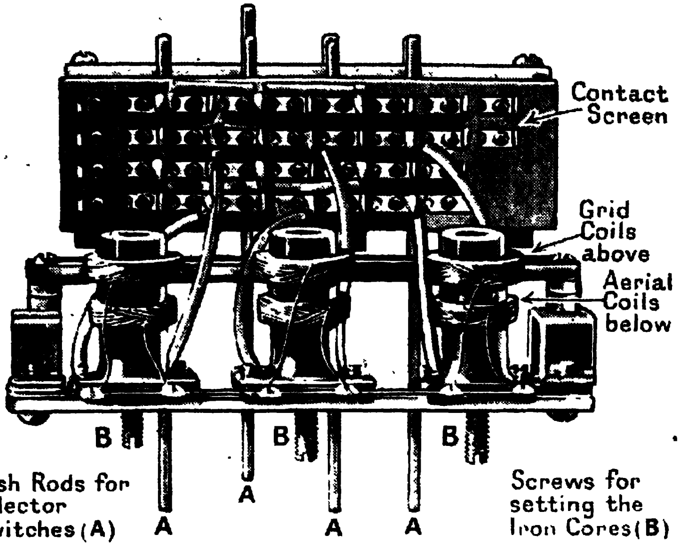
A popular feature of modern sets is automatic, or push-button, tuning. Instead of turning the gang condenser, the listener simply pushes one of a group of buttons, each of which switches in a pre-selected station.

There are various systems by which



PUSH-BUTTON TUNING COILS

Fig. 12. In one push-button system separate coils are used to tune each station. The parallel condenser is fixed, and the coil itself is given a fine tuning adjustment, when the set is first installed, through the agency of a small iron-dust core.



INGENIOUS SWITCHING SELECTS YOUR STATION

Fig. 13. **In some push-button sets a pre-tuned circuit has to be switched in at every point where normally there is a variably-tuned circuit. For example, in a set with a three-gang condenser three pre-set coils will be needed for each push-button station, as shown in this diagram.**

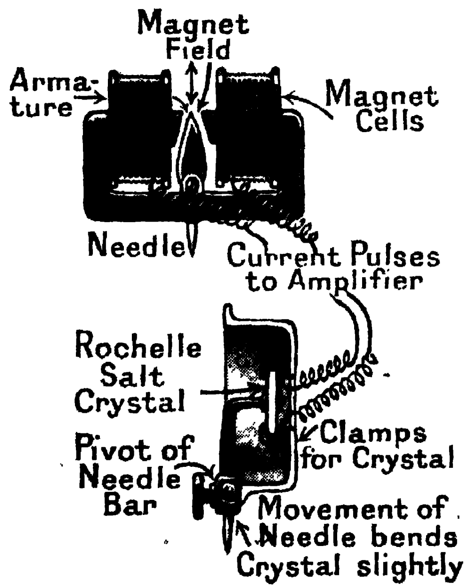
this is done. The simplest are just mechanical devices by which the pushing of the button revolves the gang condenser to the required position. In ambitious sets pushing the button may switch on a miniature electric motor, which drives the gang round until the required position is found when a contact is automatically interrupted, thereby stopping the motor.

Another method simply cuts out the gang and switches in small semi-fixed tuning condensers, which are pre-set to the required capacities. In another system, which is possibly the most popular because it gives very stable results, the tuning condensers are of fixed capacity, and different coils are switched in for each station (Figs. 12 and 13).

Our last picture (Fig. 14) illustrates two types of pick-up by which records can be played through a radio set. One consists of a small but powerful magnet on which are coils of very fine wire. Between the two poles of the magnet is an iron armature, carrying the needle.

As the record turns, the groove makes the needle vibrate at the speed of the sound waves, and this means that the armature disturbs the magnetic field. As the field moves, it induces a low-frequency current in the coils. This has only to be amplified up, usually by the triode and output stages of the set, to be audible from the loudspeaker.

The second type uses the remarkable "piezo" crystal, which produces voltages as it is bent by the movement of the needle.



GRAMOPHONE PICK-UPS

Fig. 14. **The electro-magnetic (top) and piezo-electric pick-ups (below) are here illustrated.**

HOW YOUR GRAMOPHONE RECORDS ARE MADE

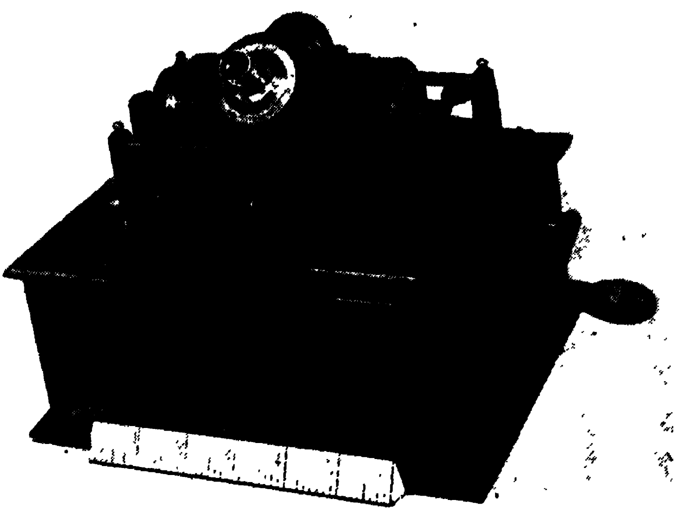
Writing in sound. Lateral recording. Disk and stylus. In the recording studio. In the recording machine room. The wax master. Outside recordings. Making the matrices. Mixing the material. Pressing the records. Inspecting and testing.

THE gramophone record is an object of everyday use which, linked with electrical reproduction, has reached a stage of efficiency bordering on perfection. Yet, so quickly do people forget their wonder in these days of scientific achievement that this amazing feat of storing up sound for future reproduction is accepted almost without question as something quite ordinary.

Superficially, one record is very much like another. It is a glossy black disk. There is no vital reason why it should be black, but custom seems to have settled it, and although coloured records have been made, black is the standard.

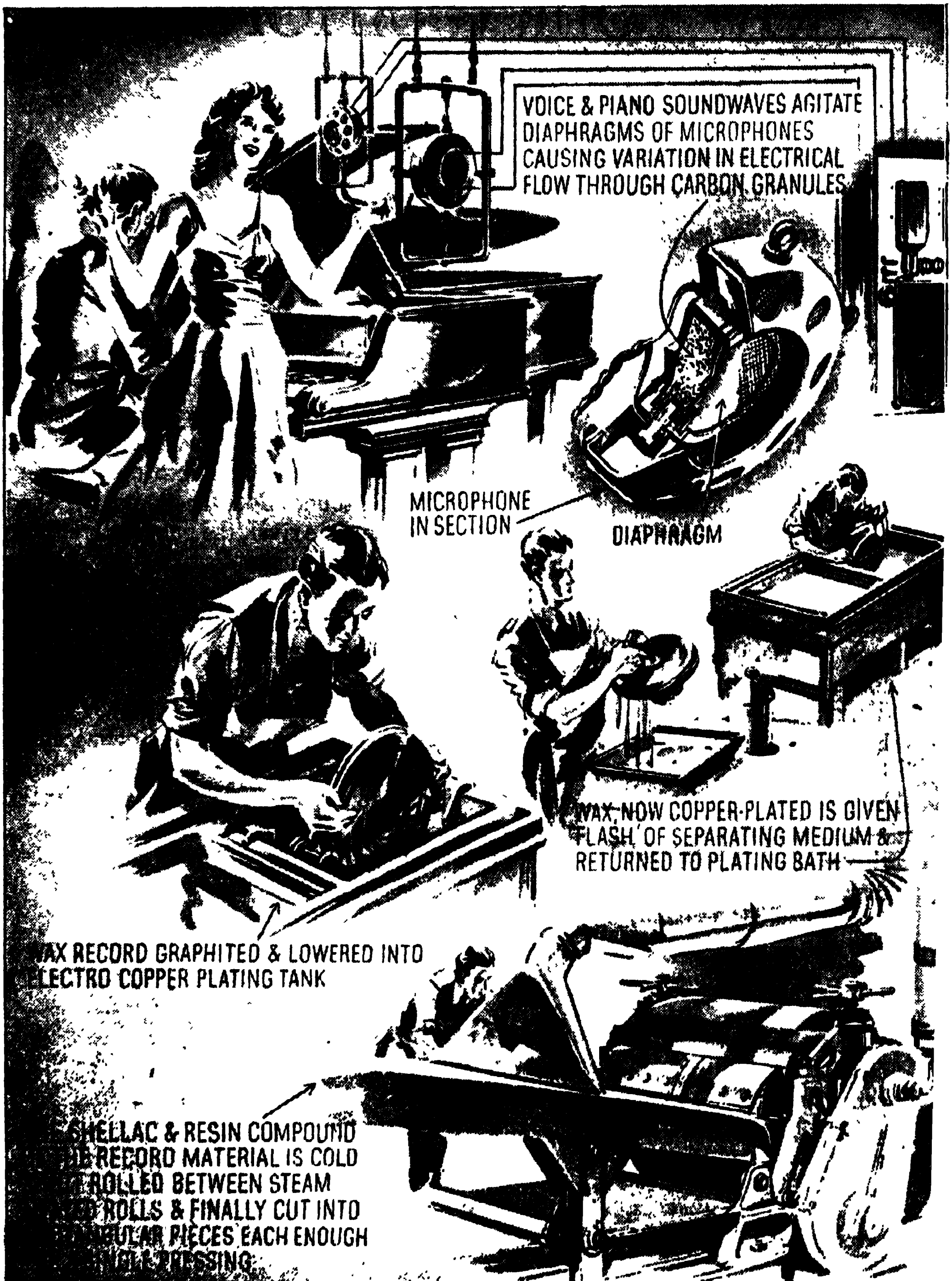
On examination the surface of the disk is seen to be covered evenly with fine grooves in the form of a continuous spiral running inwards from the outer edge. Closer inspection shows that the grooves are slightly wavy, and if the record is held so as to catch the light these irregularities break up the reflection into countless points of light. You are looking at actual "Writing in Sound."

When a body vibrates it alternately compresses and rarifies the surrounding atmosphere and the impulses are passed on and on until, if they reach the ear, they are transformed into the sensation we call sound. Both the gramophone and its one-time rival, the phonograph, were derived from the discovery in 1859 by Leon Scott, who demonstrated before the Royal Association that sound was a form of energy, and that a record could be taken of sound. His simple apparatus, which he called the "Phonautograph," consisted of a hog's bristle attached to a stretched membrane or diaphragm, mounted on the narrow end of a funnel.



PHONOGRAPH WITH CYLINDRICAL RECORD

Fig. 1. The chief difference between the early phonograph and the modern gramophone is the method of recording the sound waves.

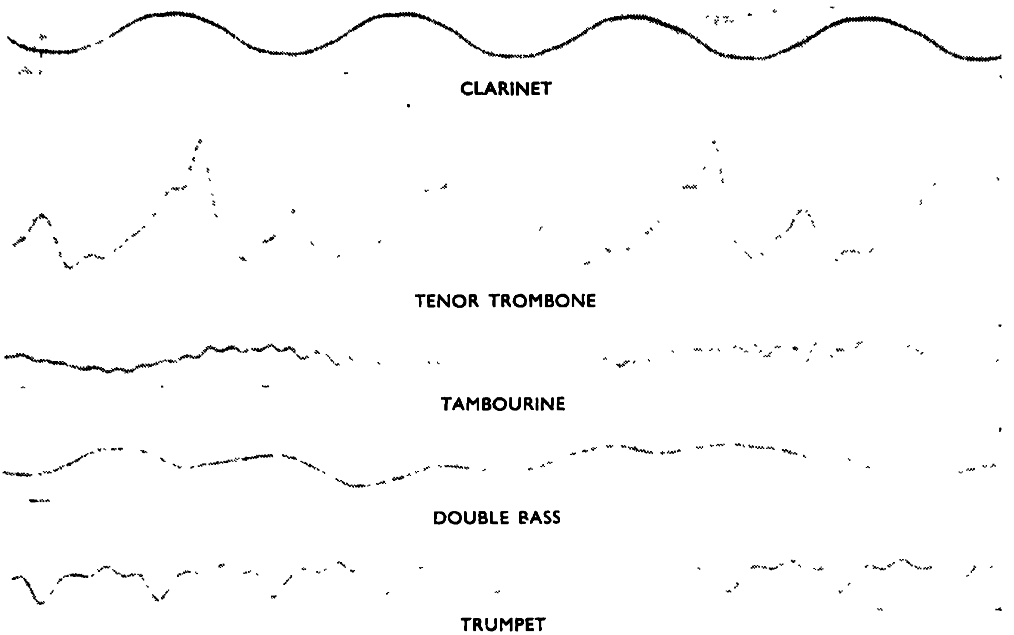


PICTORIAL SURVEY OF THE STAGES THROUGH

Fig. 2. How sound is stored up for reproduction is shown in the above illustration. Reading from left to right across, we see in sequence the stages in the evolution of a gramophone record. From the studio the sound, carefully balanced at the control panel, reaches the recording machine, where

WHICH A GRAMOPHONE RECORD MUST PASS

the sound traces are cut into blank wax. The e delicate traces are then transferred to a stronger material, electro-plated with copper, and backed with nickel. This matrix, from which numbers of copies can be taken, fits into the dies of the record press, and the glossy black finished disks emerge.



WAVE FORMS MADE BY ORCHESTRAL INSTRUMENTS

Fig. 3. A sound wave is the disturbance caused by a single vibration. This is shown consecutively as alternate crest and trough. The wave forms made by different instruments are shown above, and their frequencies, or number of vibrations which pass a given point per second, vary accordingly.

The free end of the bristle just touched the lamp-blacked surface of a cylinder which was revolved, and traversed on a screw thread, simultaneously. Sounds made into the funnel agitated the diaphragm, and the tip of the bristle made a visual record of the oscillations on the blackened surface of the moving cylinder. The "record" was a wavy line on which similar sounds made similar traces.

The instrument did not reproduce the sounds, but some years later it gave Edison the idea that resulted ultimately in the invention of the phonograph, while Berliner used it as the inspiration for the gramophone.

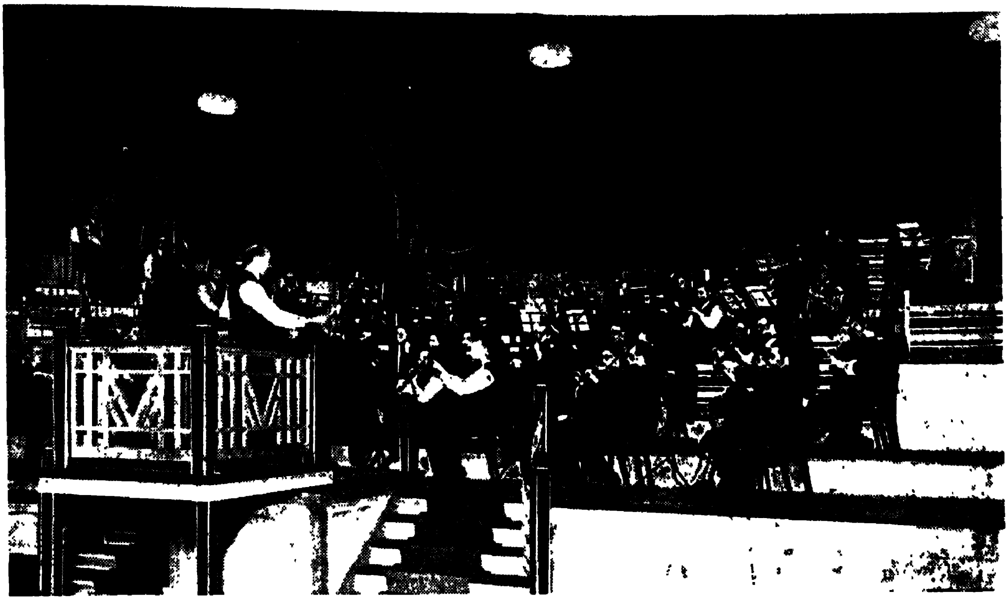
The chief difference between the two systems was that in the phonograph cylinder the sound waves were recorded on the *bottom* of the groove ("Hill and Dale" recording) while in the gramophone disk the sound waves were recorded on the *sides* of the groove, which was of even depth ("lateral" recording).

The lateral (gramophone) recording is now used universally for commercial recording although the phonograph cylinder (Fig. 1) is still a familiar sight where dictating machines are used.

A sound wave is the disturbance caused by a single vibration of a body or substance. If, for instance, you deflect the free end of a clamped stick, it will be some time before the stick comes to rest again. Meanwhile, the tip is moving from side to side of the normal position and the impulse given to the air by one small journey from the normal out on *both* sides and back to normal results in a single *sound wave*.

In a graph the complete vibration is shown as an alternate crest and trough, and in a pure musical note, such as that given by a French horn, the crest is followed by a trough of a similar shape. Fig. 3 shows wave forms for different instruments in an orchestra.

The *frequency* of a sound wave is the

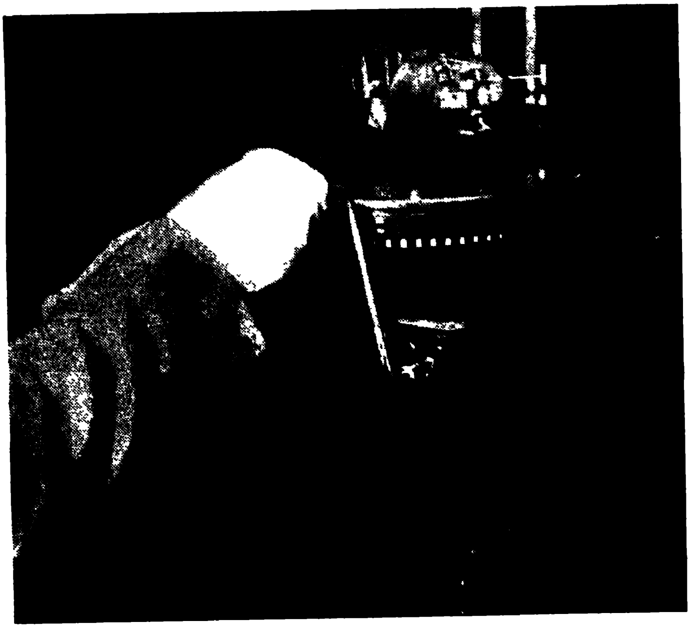


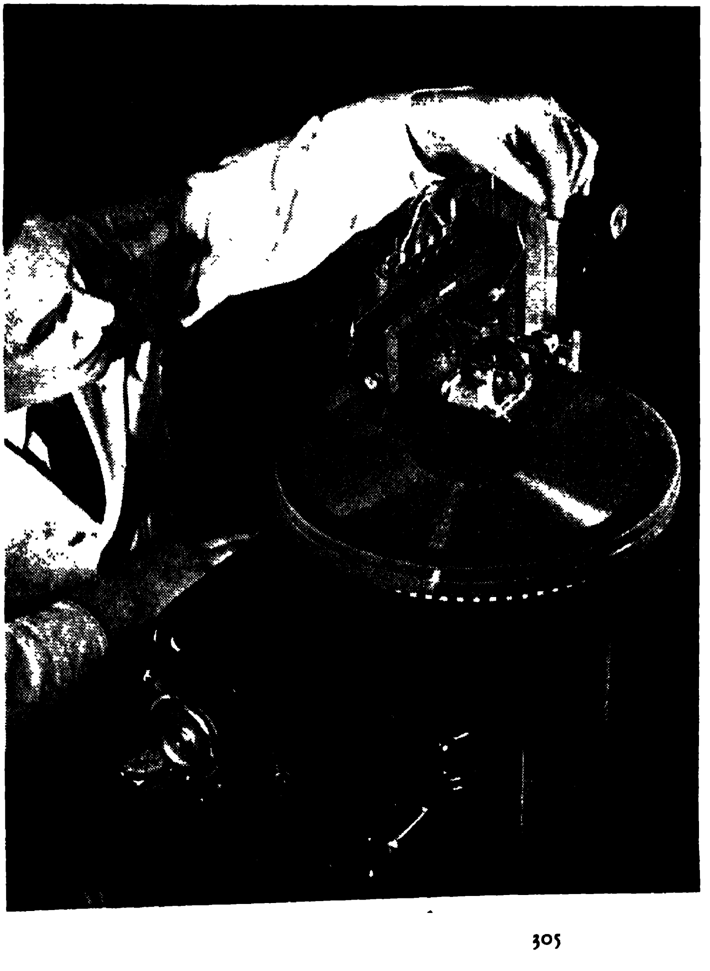
AN ORCHESTRAL PERFORMANCE IN THE RECORDING STUDIO

Fig. 4. Our illustration shows a B.B.C. orchestra conducted by Sir Adrian Boult in H.M.V.s recording studio. The modern studio, which is spacious and well ventilated, is specially constructed without any prominent curved surfaces, to prevent any extraneous sound and vibrations.

BALANCING THE SOUND AT THE CONTROL PANEL

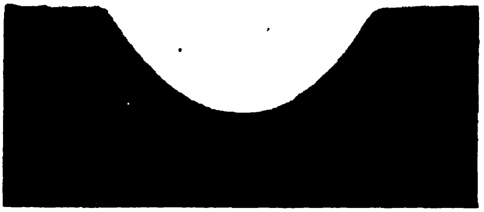
Fig. 5. The performance is sometimes received by two or more microphones, and is fed into a mixing control panel where it is balanced before reaching the recording machine, to emphasize certain instruments, correct placing of artists and microphones also ensures good balance

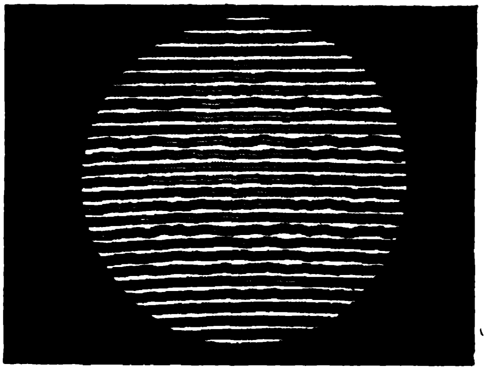


RECORDING MACHINE

Figs. 6, 7, 8, 9 and 10. Sound is recorded on the disk known as the wax master. The recording machine driven by a clockwork motor is wound up afresh for each record (Fig. 6, top left). The stroboscopic lines at the edge of the turntable test the constancy of speed, by appearing stationary when it revolves at the correct speed of 78 revolutions per minute. The cutting stylus, suspended above the turntable is lowered on to a perfectly smooth wax blank (Fig. 7, top centre). The wax is tested by cutting a few grooves on the outer edge, these being examined under a magnifying glass (Fig. 8, top right). Fine wax shavings, which are thrown off by the stylus, are drawn away by suction (Fig. 9, bottom left) to prevent them clogging the cutter. When the recording has been successfully taken, the stylus is lifted carefully from the wax (Fig. 10, bottom right), and the signal is given in the studio accordingly. If, however, the recorder detects the slightest flaw, or a mistake during the recording, he signals to the studio to stop the performance, and halts the machine, so that the correction can be made before the performers disperse.





TRACK MADE BY THE STYLUS

Figs. 11 and 12. Magnified here are the grooves cut in the wax showing the wave forms made.

number of complete vibrations or cycles which pass any point in a second. A low note is comparatively sluggish and has a low frequency, and as the pitch gets higher so the frequency increases. The normal human ear detects frequencies at about 16 to the second and ceases to respond at about 10,000 to the second.

FREQUENCY RANGE

Because of the mixture of mechanical and electrical apparatus used, the frequency range for recording purposes is less than that of the human ear. It lies between 60 and 6,000 frequencies. Below 60 the amplitude of the vibrations would cause the cutting tool to break through to the next groove, and above 6,000, surface noise would become too apparent.

The actual sound traces are cut into a wax disk, the composition of which is generally a closely guarded secret, since

THE WAX MASTER GOES TO THE RECORD FACTORY

Fig. 13. The wax master is packed in a padded, hermetically-sealed container to prevent damage in transport, each one having first been given its own number for identification purposes.

INSPECTING FOR FAULTS IN CUTTING

Fig. 14. The recorded wax master must not be played direct, but must be examined carefully by the recording engineer to whose expert eye its appearance reveals any faults in the cutting.

RECORDING IN DUPLICATE

Fig. 15. When a performance cannot be repeated, or is broken at the end of a side, duplicate recording machines are used, then, if the playback is satisfactory the wax on second machine is used as a master.

MOBILE UNIT FOR RECORDING OUTSIDE BROADCASTS

Fig. 16. This mobile recording van, used for outside broadcasts, contains a generating plant, recording machines, control panels, amplifiers, wax-heating cabinet, telephones, and all the equipment necessary for electrical recording, compactly arranged to occupy a minimum of space.

its functions are so important. It must, for example, be of absolutely consistent texture throughout, without the least trace of gritty particles or soft spots. Although in its blank state it must have a surface of glassy smoothness, it must be soft enough to take every vibration of the cutter, yet allow the result to remain unaltered. It must not chip, and the floor of the grooves must remain smooth, while the shavings turned up by the cutter must come away cleanly, without fouling the mirror surface of the wax, or clogging the cutter. Finally, it must be acid resisting and must not form a favourable ground for mould or fungus producing spores.

The cutter, which is very sharp and true and made of selected sapphire, is known as the *stylus*. It is examined microscopically at frequent intervals.

The modern recording studio (Fig. 4) is spacious and well ventilated. Special precautions are taken to prevent extraneous sounds or vibrations. There are no prominent curved surfaces, for example, which might tend to produce these extraneous sounds.

FEATURES OF A RECORDING STUDIO

In listening direct to sound we use our two ears, and are thus able to locate the source of the sound. A recording system can employ only a single sound channel, and this, if not remedied to some extent, would be noticeable in the record. To do this, use is made of one of the physical characteristics of the recording

studio, known as the reverberation time, which is the interval required by well-diffused sound to die away to one-millionth of the original intensity.

Reverberation supports the original sound and gives a realistic though artificial sense of depth and breadth in reproduction. It has also been found that musicians cannot play satisfactorily in a studio having too great or too small a reverberation. The surroundings are, in fact, referred to as "unsympathetic."

HOW A COPY IS MADE

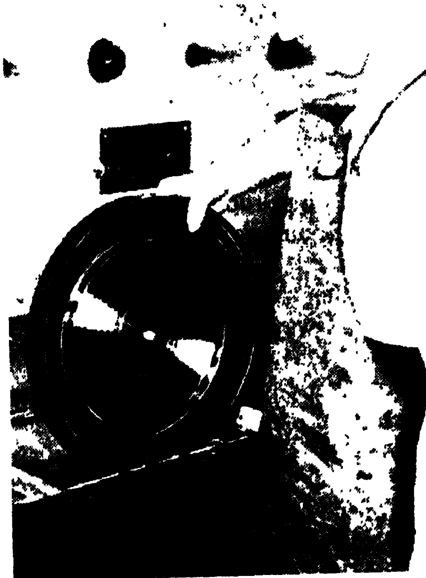
Fig. 17. To transfer the delicate traces of the sound waves to a stronger medium, the soft wax goes through an electro-plating process requiring great skill. It is first coated with graphite, and a metal pin placed in the centre, as above, makes an anode contact for electrical conduction.

Another feature of a modern studio is the art of diffusing the sound from its source, so as to avoid local reflections. The composition of the walls and ceiling also contributes to the desired result as well as the distribution, when necessary, of materials which have the effect of damping or absorbing sound.

Sometimes two or more microphones are used in different parts of the studio and fed into a mixing control panel (Fig. 5), for emphasizing certain instruments.

Different sized studios are used for recording say, a piano, a dance band or a large symphony orchestra.

Before a record can be taken, the recording expert has to place his artists and microphones in the best positions to ensure the desired effect. The greater the number of performers, the greater the problem of getting balance. This is achieved in due course, partly by the above means and partly by modifications in the electrical recording circuit.



THE COPPER SHELL IS FORMED

Fig. 18. The graphite-coated wax is lowered into the electro-plating bath. A shell of copper is deposited on its surface forming the negative master. Every detail is duplicated on the copper shell, which is stripped from the wax. This operation calls for great care, to avoid damage to wax.

NEGATIVE "MASTER" BECOMES POSITIVE "MOTHER"

Fig. 19. On the copper shell a further coating is laid which is positive. From this (known as the "mother") any number of working matrices can be obtained. This "mother" is then treated similarly, and from it grow the dies from which the actual records are pressed.

Singers unused to recording are instructed in a few of the points of microphone technique, such as to draw away a little when producing very loud notes.

One cannot help comparing this ideal state of affairs with the older methods, when recording rooms were comparatively small, and generally badly ventilated.

As all the sound vibrations had to make their way, unassisted, into the recording horn, the members of an orchestra were grouped in the oddest manner. Trombonists sat on raised seats, in order that the sounds made by their instruments should not be cut off by the heads of any vocalists. Some of the violins had horns fitted to carry the vibrations more directly to the recording horn. "Effects" were grouped as near as possible to the recording horn, generally above it, and it is a fact that on one occasion, when a sheet of iron (the "thunder") was suspended above the horn, the operator who was to strike it at the correct moment with a hammer, missed the sheet of iron and hit the vocalist on the head.

Those days are, happily, a thing of the past, and in a present-day session, all the preliminaries having been settled to the satisfaction of the recording expert, the actual recording can commence.

Meanwhile, what happens in the recording machine room? Here you see a large loudspeaker, perhaps a couple of recording machines, and a cupboard in which the blank waxes are stored.

The recording machine is really a screw-cutting lathe, in which the cutting tool is suspended above a horizontal turntable. The cutting stylus is vibrated electrically, and the machine itself is driven by a clockwork motor (Fig. 6), the motive power being a heavy weight which is wound up afresh for every record. This is to ensure an absolutely constant speed for the turntable, for any variation would result in a fluctuating pitch, and the record would be spoilt.

The turntable revolves at 78 revs. per minute, and this speed is checked both for revolutions and constancy by means of stroboscopic lines painted on the sides of the turntable. When illuminated by electric light from A.C. mains current, these lines seem to stand still when the turntable is revolving at the correct speed.

The cutting stylus is mounted into an electrical recorder (Fig. 7) which, in the form of electrical impulses, transmits the

amplifications, mixings and other refinements that the original current supplied by the microphone has undergone, in order to attain correct balance between the various frequencies.

Everything being in readiness in the studio, the recorder places a 10-in. or 12-in. blank wax on the turntable. This is so perfectly smooth that it is almost incredible that it has been "shaved" by a cutting machine. The greatest care has to be taken to keep the wax perfectly clean. A finger mark would ruin it, and even breathing would affect it. Fig. 7 shows the blank on the turntable ready for the recording to begin, but before the recording is begun the wax is tested by cutting a few grooves on its outer edge and examining these under a powerful magnifying glass (Fig. 8).

To ensure silence in the studio, the recording expert sounds a buzzer. Then he lowers the cutter on to the revolving wax and a red light signals to the studio that the microphone is "live" and that any sounds made in the studio will be recorded.

As the stylus cuts into the wax it throws off a tiny shaving which is immediately drawn into a suction tube, otherwise it might accumulate and clog the cutter (Fig. 9).

The loudspeaker by the recording machine is in action, and as it is connected to the same electrical circuit as that feeding the cutting stylus, the recorder is able to hear exactly what is going on to the wax. This is his only means of knowing, since the recording cabinet is also sound-proof, its only connexion with the studios being a double window which is closed while the actual performance is in progress.

If he detects a fault or palpable mistake he signals to the studio and stops the machine, thus saving valuable time. If not, the recording proceeds until the wax is filled and the cutter lifted from the wax (Fig. 10). The buzzer then gives the all clear and the red light in the studio goes out. Fig. 11 shows the cut made by the stylus on the wax blank and Fig. 12 a portion of the record, highly magnified, showing the wave forms made by the stylus. The wax master is then examined by an expert to see if any faults have been made in the cutting (Fig. 14).

The next stage is the play back, for which purpose a light electrical pick-up is used. The vibrations pass through an amplifier and are reproduced on the loudspeakers in the studio and the recording

THE FINISHED MATRIX IS SCRUTINIZED UNDER A MICROSCOPE

Fig. 20. The working matrix is backed up with metal, but before fitting it into the record press, microscopic examination is necessary, as the slightest flaw would soon be magnified so as to become a serious one under the pressure of 1,250 lb. per sq. in., at which the press is operated.

FINAL STAGE IN THE

Figs. 21, 22 and 23. The press, driven by hydraulic pressure, consists of steel jaws, hinged like the covers of a book. "Biscuits" of material are laid on the hot plate of the press (Fig. 21). At the same time, the working matrices, fitted into the upper and lower jaws, are steam heated and the labels

machine room. If the balance is at fault, the recorder makes his adjustments and the whole process is repeated. If everything goes well, the new wax, known as the "wax master" is given its identification number and placed in a padded container for transport to the record factory, where it undergoes the next stage in manufacture (Fig. 13).

Sometimes, when a performance is of a particularly exacting nature, or a large orchestra is employed, duplicate recording machines are used, as shown in Fig. 15. Then, if the play back is satisfactory, the unplayed wax on the second machine is used as the master and a further recording is not necessary. Since only a perfect result can be accepted, however, a half-day's hard work may sometimes result in only a single satisfactory wax.

Naturally, the ideal conditions for recording are in the specially designed studios, where performances can be repeated and adjustments made until the best possible result is achieved.

Sometimes it is necessary to record away from the studios. It may be an excerpt from a variety show, when a

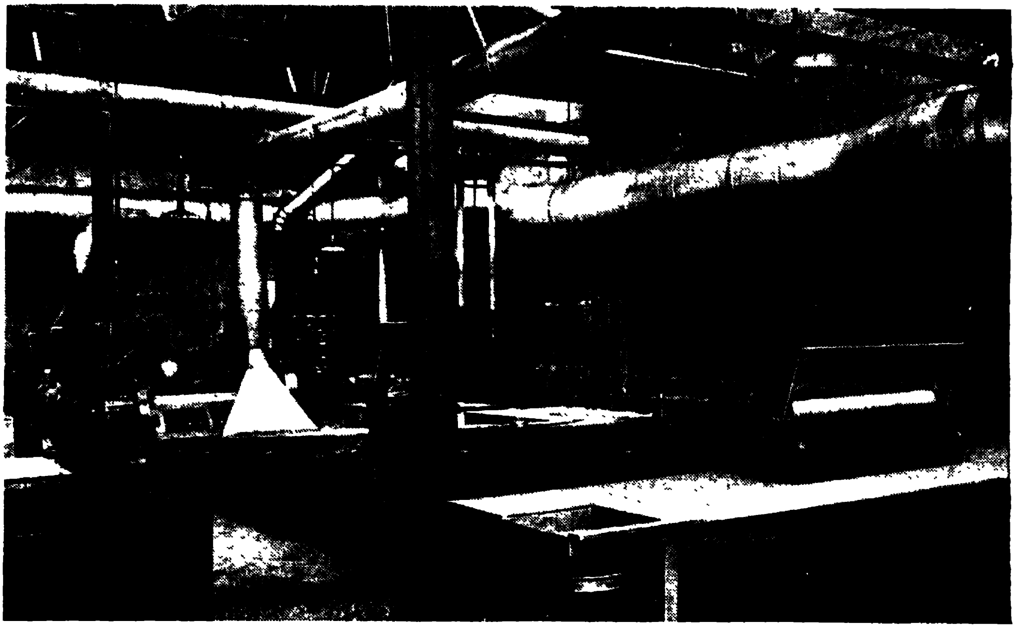
MAKING OF A RECORD
placed in position. When plastic, the "biscuit" is removed from the plate (Fig. 22) and shaped into a ball which is placed in the centre of the bottom label (Fig. 23). An even pressure is applied while hot, and the dies are water cooled immediately after, so that the record can be removed with ease.

comedian needs the "atmosphere" of a receptive audience, or an out-door function such as a Military Tattoo in which several hundred bandsmen are taking part. The Coronation Service was recorded over a land line at the time when the B.B.C. broadcast was taking place.

For the outside broadcasts a mobile recording unit (Fig. 16) is used. This is a large van containing generating plant, recording machines, control panels, amplifiers, wax heating cabinets, telephone equipment and all the paraphernalia necessary for electrical recording. The van is also equipped with hydraulic apparatus to lift the wheels from the ground and minimize vibration.

In these cases, when it is not possible to pre-arrange the performance in requisite lengths each to fit a side of a record, the recording is continuous, and the following side is commenced while the previous side is still being recorded. The whole recording is also taken in duplicate. Afterwards chosen portions are re-recorded on to fresh waxes.

Land (telephone) line recordings are taken direct to the recording room.



MIXING THE INGREDIENTS OF WHICH RECORDS ARE MADE

Fig. 24. The brittle sheets from which the "biscuits" are cut are composed of finely ground ingredients which have been mixed into a plastic dough between heated rollers. The dough is then passed through a further set of water-cooled rollers to reduce the temperature back to normal.

treated as continuous performances, and similarly divided and re-recorded.

This re-recording or transferring of one record to another is a modern practice, and is now carried out with such efficiency that it is difficult to say which is the original and which the transfer.

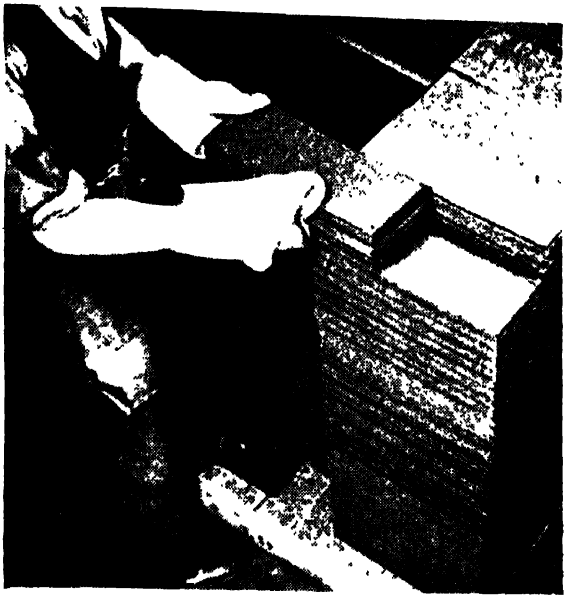
It is useful in many ways. For example, a record may have proved just too long for commercial purposes in which set standards have to be fixed for economical production. Yet it may be impossible to shorten the music by a single bar. Such a record could be transferred by using a slightly finer recording groove, to keep it within the required limits.

Perhaps the most notable instances have been the "re-creations" of recorded performances made in the old days of mechanical recording. The weakest part of these older recordings was the orchestral accompaniments. By re-recording and super-imposing a new orchestral accompaniment, at the same time correcting electrically some of the faults of the older vocal recording, a series of really amazing results was obtained.

The process was, however, extremely difficult, particularly for the conductor. In the normal way he could listen to the living singer, watching and following every variation in tone and tempo. For a "re-creation" he had first to memorize every note of the older record in order to know exactly the smallest idiosyncracies of the artist. Then, listening to the old record by means of earphones, he had to guide the orchestra, so that the new accompaniment completely obliterated the one on the older recording.

The old introduction was cut out entirely and a new one substituted, a matter of very precise timing. Although successful, it was found that only a very limited number of older recordings repaid the enormous amount of time and effort involved in the "re-creation."

It is now necessary to transfer the delicate traces of the sound waves to some stronger medium from which metal



THE RAW MATERIAL

Fig. 25. After the mixture has been rolled out into sheets of even thickness it is cut into rectangular " biscuits " containing enough to make a ten- or twelve-inch record.

left. Therefore, the only pressings made from it are used for musical and technical testing purposes.

If these tests prove satisfactory the negative copper shell, known as the "master" is then put into a further plating bath and another positive shell deposited on to it. Before this, it is "flashed" with a thin coating of a separating medium to prevent the second shell from adhering to its surface. Fig. 19 shows the copper shell being separated after this operation.

Shell No. 2 being a positive, is no good for pressing records, which would all be negatives, but, known as the " mother " it forms the means from which further negative working matrices can be obtained.

This "mother" is then treated similarly, from it growing the dies disks can be made for the pressing of any number of copies.

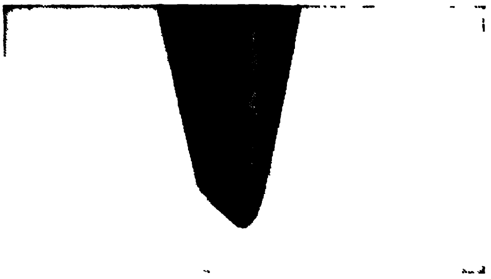
The recorded wax is first carefully coated with graphite to make it conductive, a process calling for great care and skill, and a central metal pin is inserted to form the anode (Fig. 17). It is then placed in a special holder and lowered into an electro-plating bath as shown in Fig. 18, where it revolves slowly for some hours, during which a shell of copper is deposited or grown on to the recorded surface of the wax.

Every detail is duplicated on the copper shell, which is stripped from the wax. This operation usually results in damage to the wax, so that it is obvious why so much care must be taken over this part of the process.

If we regard the original wax as a "positive" this first copper shell is a "negative" and from it further positives could be pressed. This shell, however, is too precious to be used for pressing records, as it is now the only record

THE FINISHED ARTICLE

Fig. 26. The jaws of the press open and the shining disk is revealed ready for smoothing.



THE POINT OF A WORN NEEDLE
Fig. 27. A much worn needle becomes too large for the sound track and will damage the grooves.

from which the records are pressed.

The copper surface of the working matrix would soon wear under the great pressure used to obtain the records and it is hardened by a nickel deposit. The centre hole is then drilled, another delicate operation calling for the utmost precision, as the slightest variation from the true centre would cause the record to "swing," which would result in a record that played in a wavering pitch.

The working matrix is then backed up with metal and prepared for fitting into the die of a record press. It is examined under a microscope for any flaws (Fig. 20).

The material from which records are made is a mixture of shellac, resin and other ingredients graded to insure an even texture, which form a black substance that becomes plastic when made hot, and hard when cooled.

The assembled ingredients are first ground finely, and then mixed into plastic dough between heated rollers. This is then passed through a further set of water-cooled rollers, from which it emerges in thin brittle sheets (Fig. 24). These sheets are cut into rectangular "biscuits" containing enough material for a 10-in. or 12-in. record (Fig. 25).

All is now ready for the final stage, the actual pressing of the record from the working matrix. The power used is hydraulic pressure, and the press consists of two heavy steel jaws hinged like the covers of a book, into which the working matrices, one for each side of the record, can be fitted. The top plate also holds the peg which makes the centre hole. Behind the matrices are cavities through which first steam and then cold water can be circulated.

The operator has a supply of the requisite size of "biscuit," one piece of which he places on a hot steel plate beside the record press, so that it again becomes plastic (Fig. 21). At the same time the matrices are steam heated. Record labels are placed in position, one in the centre of each matrix with the printed surface outwards. The softened biscuit is then removed from the hot plate (Fig. 22) and shaped into a ball, which is then placed on to the centre of the bottom label as shown in Fig. 23. The jaws are closed and an even pressure of 1,250 lb. to the square inch is applied. Almost immediately the matrices are water cooled, and when the jaws of the press are opened, the shining disk is revealed (Fig. 26). The whole cycle of pressing takes about thirty seconds.

The reproduction of a record back into sound is somewhat of a reversal of the recording. The needle point picks up the vibrations and transmits them to a diaphragm, whence they are amplified by passing through a tone arm and a scientifically proportioned horn, finally making their way out of the instrument.

HOW A NEEDLE SHOULD FIT THE GROOVE
Fig. 28. This new steel needle exactly fits the sound track, illustrating why needles must be changed frequently to preserve the record.

FINISHING GRAMOPHONE RECORDS BY SMOOTHING OFF EDGES

The record is removed from the press, and after the superfluous material has been broken away, it is put on to a buffing machine for the edge to be smoothed.

INDEX

NUMBERS IN ITALICS INDICATE ILLUSTRATIONS

Aberbargoed Hill, 219
Accumulator, nickel-iron, *21*
Aerial spreader, *113*
Agitator brush, *155*
Air conditioning, 277–284
  Distribution of, 279
  fan, 16
  heaters, Finned, 279
  system, *56*
Alarm calls, Receipt of, 227
  clocks, 126
Alternating current, 297
Alto-cumulus cloud, *239*, 240
Alto-stratus cloud, 234, *238*
Ammonia gas, 138
Amplification of valves, 295
Amplifying valve, 292–293
Anode, 287
Anthracite, 7
Anticyclones, 233
Apparatus of telephone exchange, *109*
Aqueducts, 73
Arbor barrel, 115, *117*
Arc lamp, Carbon, 256
Artesian wells, 72
Artificial silk, Finishing, 146
Automatic junction, 164
  prepayment meter, 50
  signals, *162*
  telephone exchange, *99–102*
  telephone system, 104
  valve, *282*, 283
  volume control, 295

B

Bacillus coli, 79, *83*
Bacteria in food, 131
Bag-wash, 150
Balanced sector gates, 246
Balancing sound, *303*, 309
Ball-valve, 88
Barrel, Arbor, 115, *117*
Batteries, H.T. and L.T., 289–290
Battersea Power Station, 55
Beam wireless stations, 201
Belt, Conveyer, *33*
  drive, 279
Berliner, 302
Bjerknes, V. and J., 234
Blankets, Drying, 146
Blind division, The, 182
Boiler, Cleaning the, 91
  The domestic, *93*, 94
Boilers, Hot water, 91
Bowden cable, The, 260
"Brain" of the automatic lift, 270, *275*
Brake governor, The, 163
Brattice screens, *16*, 17
British National Grid, The, 61
Broadcasts, Outside, 313
Brunel, 197
Brush-roll, The, 156
Buffer, 146
Bus drivers' training, 220
  route, Mileage of, 212
  transport, how it is organized, 207–222
  transport, Types of, 207
Buses, Overhauling, 220
  Washing, *222*

C

Cable chamber, *109*
  making, 69
Cables, Repairing, 200
  Submarine, 197
Cage, Pit, *9*
Calyx tool, *8*
Canal Locks, Emptying and filling, *247*
  how they work, 243–252
  Sizes of, 243
  Structure of, 245
Carbon arc lamp, 256
  dioxide extinguisher, 262, *264*
  tetrachloride, 262
Carbonization, 37, 40
Carburettor, 44
Carrier waves, 112, 285
Cathode, 290
Change machine, *172*, 174
Change-over cue, 260
"Cheese", A, *143*
Chiming barrel, *124*
  clock, 119
  clock, Parts of, *123*
Chlorination of water, 80
Chocks, *22*
Cholera vibrios, *83*
Cinema films, how they are projected, 253–260
Circuit breakers, 67
  Tuned, 286, 291
Circuit, Primary, 92
  Secondary, 92
Circulation lists, 181
  of water, 89
Cirrus cloud, 234, *238*
Classification of laundry, 140
Cleaners, Vacuum, 151–157
Cleaning attachments, *155*
Click spring, *125*
Clock, Parts of the, *119*, 123
  Types of, 115–130
Cloud formation, *238–239*
Coal, how it is brought to your home, 5–29
  Composition of, 8
  cutter, *18*, *24*
  Formation of, 5
  Prospecting for, *8*
Code selectors, 112
Coke grading plant, *49*
  oven plant, *41*, 43
  plant, 47
Coil, Tuning, 286, *287*
Combustion chamber, 37
Compressed air turbine, 25
Compression of gases, 136
  type refrigerator, 136
Condenser, 286–287
  gas discharge tube, 223
  pipes, *38*
  Primary, 38
  Secondary, 38
  tuning, 298
Conductor's waybill, 221
Contactors, 271
Controller of lift, 270
Control-room of power station, *60*
  -room of fire station, 229
Conveyer, 25–26
Cooling air, 284
  pond, 60
  tower, 60
  unit, 283
Counterweight, 269
Culverts, Permanent, 247, *248*
Cumulo-nimbus cloud, 236, *239*
Cumulus cloud, *239*, 240
Current, a.c. and d.c., 54, 297
Cylindrical type cleaner, *152*, 153
  sluice, 247, *248*

D

Dampers, Adjustment of, 94
Damp-wash service, 150
Dams, 72
Davy lamp, The, 20
Dead man's handle, The, *163*
Demodulation, 294
Depression, A November, 233
Detection, 294
De-watering a mine, 15
Diamond tool, The, *8*
Diaphragm of a telephone, 100
Dies, Record, 316
Diesel engines, 217
Digit selector switch, 111
Diode valve, 294
Direct current, 298
Dirt, Types of, 151
Disk, Gramophone, 308
Distorting apparatus, 114
Distribution of Air, 279
  frame, 110
  of gas, 46
Domestic boilers, *93*, 94
  refrigerators, 134
Double pole switch, 67
Down special, The, 191
Downward system, The, 282
Dry pipe system, 265
Dust bag, 152
Duty roster, The, 221
Dynamo, Principle of the, *59*

E

Echometer, 199
Edison, 302
Elan, The River, 72
Electric clock, The, 128
  eye, The, *275*, 276
  lamps, *21*
Electrical appliances, 69
  recorder, 310
Electricity, Discovery of, 53
  How we harness, 53–69
  in the home, 69
Electro-magnet, Principle of, 103
Electrons, 286
Electro-plating bath, 315
Endless rope, 268
Escalators, 176
Escapement, 115, *117*
Evaporator, 137
Exhauster pumps, 38
Explosions in mines, 20
Extinguishers, Fire, 261–265
Extract fan, 282
  grilles, 282

F

Fan extract, 282
  vacuum cleaner, 153
Faraday, Michael, 53, 64
Feeding teams, 144
Filament, 287
Film focusing, 256
  frame, 253, *254*
  Lacing up, 253
  lighting, 256
  projector, 253, *257*
Filter Beds, 79
Filters, Primary, *82*
Filtration of water, 77
Finishing laundry, *144*
Finned air heaters, 279
Fire alarm boxes, Mechanism of, 227, *228*
  What happens when you sound a, 227, 232
Fire damp, 17
  extinguishers and sprinklers, 261–265
  station control-room, 229
  trap, 259
Flat-iron, 141
Flat-work, 144
Flicker blade, 256

Floor relay, 271
  selector, 272
Flying junction, *164*, 169
Foam extinguisher, 261, *263*
  hand-pump, Portable, 262
Focusing films, 256
Food Act, 1928, 131
  Decomposition of, 131
  placing in the refrigerator, *133*
  Sterilization of, 132
Foreign Mail, 194
Formations of cloud, 238–239
Foul main, The, 38
Frequency converter, 292
  Intermediate, 291
Frequencies, Beat, 293
  Low, 286
Fresh air grilles, 282
Fuel, Types of, 94
Furnace system, *56*
Fuses, 67

G

Galvanometer, *54*
Garage, allocation by buses, 219
Gas, Composition of town, 31
  Distribution of, 46
  How it is produced, 31–51
  meter, Dry, *50–51*
  meters, Wet and dry, 47
  producer, *40*
Gasholders, Types of, 45–48
Gases, Compression of, 136
Gasworks, Layout of, *34–35*
Gathering pallet, 121
Geysers, how they work, 96
  Types of, 94
Generating system, *57*
Goaf, A, 21
Governor of clock, 115
Graig Goch reservoir, *77*
Grand Union Canal, The, 244
Grapnel, A, 200
Grid, 287
  bias, 295
Grid, British National, The, 61
  system, how it works, *63*
Gramophone disk, 308
  pick-up, The, 316
  records, 299–317
Group selectors, 107, *110*
Grouting, *14*
Guide-framed gasholder, *45–46*
Guide rails, *46*
  rollers, *46*

H

Hammer spring, *122*
  stop, *122*
Hardstone, 14
Hard water districts, 91
Hawkeswater Dam, *76*
Headgear frame, 27, *28*
Headstock, Interior of, *9*
Headway charts, 167, *169*
  clocks, *167*, 169
Height gauge, *209*
High frequency waves, 306
"Hill and Dale" recording, 302
Hill, Sir Rowland, 191
Hoppers, 36
Horizontal retort, *40*
Hot-air chamber, 146
  tumbler, 146
Hot water system, 87
Hour-lifting piece, 124
Hour wheel, *118*
Household hot water, How you get
    your, 87–98
Hydro-extractor, The, 141, *145*
Hydrogenation process, 8

I

Icebox, 135
"Idle rope," The, 267
Immersion heater, Electric, 96, *98*
Impulse train, 106
Indirect system, The, *91*, 92

Inductor switch, 272
Instantaneous heater, 95
Intakes, 80
Inverts, 243
Ironing, Methods of, 146
Irons, Types of, 141
Isobars, 237

J

Jacks, 104
Junction, Automatic, 164
  Flying, *164*, 169

K

King Edward building, 187, 195

L

Lacing-up films, 253
Lagging, 133
Lamp, Safety, 17, *20*
  Electric, *21*
Larry, A, *36*, 40
Lateral recording, 392
Laundry, Classification of, 140
  How a, washes your clothes,
    139–150
  Finishing, 144
  Marking, 140
Lay-by line, 173
Layout of gasworks *34–35*
  of line, *171*
  Terminal, *170*, 172
Letter, What happens when you
    post a, 181–195
Lift, What happens when you use
    a, 266–276
  Automatic brake, 269
  Automatic push-button, 267
  "Brain" of the automatic, 270, *275*
  controller, 270
  Electrically operated, 267
Lifts in tubes, 178
  limiting device, 226
  Speeds of, 274
Livesay washers, 38
Lock depths, 244
  flights, 249, *251*
  gates, *244*, 245
Locking mechanism, 270, *273*
London Passenger Transport Board,
    159, 207
London's buses, Evolution of,
    214–215
Longwalling, *22*, 24
Loop system, 230
  terminal, *170*
Loudspeaker, moving coil, The, 296
  The principle of, 296–297
Low frequencies, 285

M

Mackerel sky, *239*, 240
Magnetic inductor switches, 271
Mailbags, Securing, 185, *187*
Mail, Foreign, 194
  Picking up and setting down, *193*
Mains valves, 297
Manchester Ship Canal, The, 243
Marconi, 198
Mare's-tail sky, 243, *238*
Marking laundry, 140
Matrix, Working, 315
Measuring wheel, The, 210
Meter rack, 109
Meters, Automatic prepayment, 50
  Gas, 51
  Venturi, *74*, 80
  Waste-detecting, 86
Methane, 17
Methyl-bromide extinguisher, 262
Metropolitan Water Board, The, 80
Microbes, Types of, 83
Microphones, 285
Mileage of bus route, 212
Mine, De-watering a, 15
  Parts of, *12*
  Ventilating system of a, *16*

Miner's equipment, *19*
  tools, 25
Mines, Depths of, 29
  Explosions in, 20
Minute wheel, *118*
Mitre, 243
Mixing control panel, 309
Mobile recording unit, *308*, 313
  telegraph, 205
Morse code, The, 203
"Mother," The, 315
Moving-coil loudspeaker, 296
Multi-roll flat work ironer, 141
Murdoch, William, 31

N

Napthalene, Removal of, *43*
Nickel-iron accumulator, *21*
Nimbo-stratus cloud, 234, *239*
Non-sync., 254
Northern General Transport, 218

O

Oil fires, Extinguishing, 262
Outside broadcasts, 313
Overhauling buses, 220
Overspeed governor, 268

P

Paddles, 247
Pallets, 115–117
Passenger car lift, 267
Pendulum, The, 115, *118*
Pentode valve, The, *291*
Permanent culverts, 247, *248*
Phonautograph, The, 299
Phonograph, The, *299*
Photo cell unit, 276
  -electric cell, 259
Pick-up, The gramophone, 298
Picture telegraphy, 202
Piezo-electric system, The, 298
Pillar and stall method, The *22*, 24
Pistol extinguisher, The, 262
Pit trucks, *18*
Plastic range, The, 38
Playback, The, 311
Plenum plant, 277
Pneumatic doors, 177
Polar Front theory, The, 234
Portable domestic cleaners, 153
Post Office, Mount Pleasant, 185,
    190
  Radio Station, 113
  railway, The, 187
  travelling, The 191
Power plant, *56*
  control-room, *60*
  station, Battersea, *55*
Pressing laundry, 144
  records, 316
Pressings, Test, 315
Primary circuit, The, 92
  condenser, The, 38
  filters, *82*
Producer gas, 41
Producers, Gas, 37
Projector, Film, 253, *257*
Prospecting tool, 11
Pruning bus, The, *211*
Pumping processes, 82
Pumps, Water, *81*
Purification of gas, 38
Push-button tuning, 298
Pylons, *65*

Q

Quartzoid bulb sprinkler, 264
Quick-gravity filter beds, 77
Quoin, 243

R

Racking, 147
Radio gramophone, 298, 316
Radio set, how it works, 285–2
  telegraphy, 201
  telephony, 112
Ramp, Retiring, 270

Ratchet wheel, 117
Receiver, Telephone, 100
Recorder, Electrical, 310
Recording machine, 305–310
  studio, Features of, 308
  unit, Mobile, *308*, 313
Recording unit, Mobile, 313
Record Press, 316
  reproduction, 316
Rectification, 294
Rectifier, 298
Refrigerator, how it works, 131
  Parts of, 132
Refrigerators, Types of, 134
Registered letters, 182
Regulator of clock, 115
Relays, 271
Repeater station, 114
Re-recording, 314
Reservoir, London's natural, 71
Reservoirs, 72
Retiring ramp, 270
Retort, 37
  Horizontal, *40*
  house, 36, *40*
  Vertical, 41
Returned letters branch, The, 182
Reverberation, 309
Reversers, 271
Ribbon storage train describer, *166*
Robot switch, *102*
Rolling stock, Bus, 217
  stock, Tube, 176
Rotary washers, *43*
Rotor, 130
  wheel, 128
Rugby, Beam telegraph radio station, 201
  post office station, 113

S

Safety lamp, 17, *20*
  precautions in tubes, 163
Sandstone, *14*
Scale, Deposits of, 91
Scott, Leon, 299
Screen Grid valve, *292*, 293
Secondary circuit, 92
  condenser, 38
  sorting, 184
Selector mechanism, 106
  racks, 110
  switch, 271
Shaft, Lining a, 14
  Sinking a, 11
Shaker screens, *10*
Shaking screens, 28
Shale, 28
Sheets, How to wash, 141
Shirt unit, 144, *148*
Shutter, The, 256
Side ponds, 248, *249*
Signalling in tubes, 161
Signals, Automatic, *162*
Single-leaf gate, 246
Slip ratchet gearing, 153
Slot meters, 50
Slow filter beds, 77, *79*
Sluice, Cylindrical, 247
Sluices, 248
Snail, The, 116
Soda-acid type extinguisher, 261, *262*
Sorting carriage, The, 194
  coal, 28
  letters, 181
  primary and secondary, 184
Sound, Balancing, 303–309
  gate, 256
  optical system, 258
  track, *254*, 258
  vibrations, 99
  waves, Frequency of, 302
Spherical pressure gasholder, *48*
[illegible]older, *46*
4

Sprag, *23*
Spray and jet nozzle, 261
Sprinkler installations, 263
Stamp cancelling, *180*, 181
Starched articles, 146
Startor, 128–130
Star wheel, *121*
S.T.L. type bus, 217
Steam system, 57
  winding engine, *27*
Stepping down voltage, 64
Sterilization of food, 132
Stethoscope, 86
Stopcocks, 85
Storage heater, Gas, 95
  Electric, 95, *97*
Streptococci, *83*
Stroboscopic lines, 310
Stylus, The, 308
Submarine cables, 197
Suction cleaner, 153
"Suds," extinguisher, 261
Sulphur dioxide, 136
Survey instruments, 212
  party, 212
Switchboard, The telephone, *101*
Synchronizing sound and film, 259
Synchronous motor clock, 128
Synoptic charts, 236
Syphon tube, 224

T

Take-off sprocket, The, 254
  spool, The, 259
Talybont reservoir, *78*
Tandem selector, 112
Tangential gear, *51*
Telegrams, What happens when you send a, 197–205
Telegraph, Mobile, 205
  ships, 198
Telegraphy, Picture, 202
  Radio, 201
Telephone, Dial of the automatic, 105
  Exchange, Automatic, *99*, *102*
  Exchange, Apparatus of a, *109*
  Diaphragm of, 100
  Receiver, 100
  switchboard, The, *101*
  system, Automatic, 104
  transmitter, 100
  What happens when you, 99–114
Teleprinter, The, 197, *198*
  code, The, 204
Temperature of air, Maintaining, 283
  of water supply, 93
Terminal layout, *170*, 172
  loop, *170*
Testing water, 79
Test pressings, 315
Tetrode valve, 290
Thermionic valves, 114
Thermostat, 137, 283
Thirlmere, Lake, 72
Three-wire system, 66
Ticket machines, *173*
  punch, The, 221
Tilmanstone colliery, 15
Tilting test, *213*
Tipplers, *10*
Topping-up, 144, *146*
Towels, Drying, 146
Town gas, Composition of, 31
Track circuiting, 161
Traffic analysis, 211
  Commissioner, The, 217
  detectors, 226
  lights, How they work, 223–226
  loads, 208
Train describer, ribbon storage, 164, *166*
Training bus drivers, 220

Transformer, Principle of the, *293*, 296
Transforming system, 65
Transmitter, Telephone, 100
Trap-gate lock, 246
Travelling post office, The, 191
Triode valve, 290, *291*
Tripcock, *162*
Tube railway, how it works, 158, 179
  rolling stock, 176
Tumbler, Hot-air, 146
Tuning circuit, 286
  coil, 286, *287*
  condenser, 298
  Push-button, 298
Turbine, 54
  Compressed air, 25
  system, 57
Turbo-alternator, *58*
Turbo-generator, *58*
Turncocks, 85
Turntable, Speed of, 310
Twin press, 144, *148*
Typhoid bacilli, *83*

U

Undercutting, *23*
Underground trolley, *9*
Universal radio sets, 298
Up Special, The, 191

V

Vacuum cleaners, how they work, 151–157
Vacuum cleaning plant, 152
  services, 152
Valve, Automatic, *282*, 283
Valve chamber, 48
Valves, Thermionic, 114
  Types of, 290–297
Ventilating a mine, 15
  louvres, 279
  system, 16
  tubes, 178
Venturi meters, *74*, 80
Vertical retort, 41
Vibrator, 156
Vibrios, Cholera, 83
Voltages, Transforming, 297
  Stepping down, 64
Volume control, Automatic, 295

W

Washing buses, *222*
  machine, The, 140
Wastage of water, 84
Waste detecting meter, 86
Water Board, The Metropolitan, 80
  Chlorination of, 80
  Circulation of, 89
  -cooled safe, 134
  Drinking, 74–75
  Filtration of, 77
  gas, How to make, 44
  How it comes to your tap, 71–86
  mains, 86
  pump, *81*
  Sources of, 71
  sump, *16*
  supply, Temperature of, 93
  testing, 79
Waterless gasholder, *30*, 46 *7*
Watt, James, 31
Waves, Carrier, 285
Wax master, The, 312
Waybill, The conductor's, 221
Weather forecaster, The task of, 236
  how it is foretold, 233–241
Wells, Artesian, [illegible]
Wet-pipe system, 265
Winding gear, *11*, 28
  Lift, 267
Worm, 130
  reduction gearing, 269

S.243. Printed in Great Britain by Odhams (Watford) Ltd, Watford